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SHIP-TO-SHORE DATA COMMUNICATION AND PRIORITIZATION

by

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14. ABSTRACT
Ships are plagued by connectivity issues while underway resulting in backlogs of data needing to get off a ship. This capstone project's main focus was to provide the Commanding Officer (CO) the capability to select and prioritize outgoing data flow from ship-to-shore dependent on their ship's operational situation while afloat. In carrying out this effort, the team focused its analysis on the Navy's Automated Digital Network System (ADNS) and Information Technology (IT) (i.e., shipboard networks and applications) communities. In so doing, the As-Is technical status and current state of business processes were captured as a starting point for the work. The team learned that the shipboard IT infrastructure, ADNS in particular, has the technical capability to prioritize data but that functionality is difficult to use and not widely understood by shipboard operators. As a result, most prioritization efforts are done ashore (instead of on the ship) which, in turn, puts extra work load on shore activities. The ADNS community is striving to make improvements in its Quality of Service (QoS) (prioritization of network traffic) and this effort is well underway. Although the technical infrastructure seems to be in place, the functional (user perspective) aspect of ship-to-shore data prioritization does not seem to be well organized and formed. This is probably one of the main reasons why data prioritization seems to be performed in a stove-pipe, fragmented, and ad-hoc manner, and conducted ashore instead of on the ship. Thus, a framework providing a ship-to-shore data prioritization perspective from a systems point of view appears to be missing. This framework could bring the functional and technical aspects of data prioritization together. Although, the team initiated the formulation of this framework in several ways. First, the team developed and introduced a conceptual prioritization matrix which would allow the CO to select and prioritize outgoing data based on the ship˝s operational situation. Second, the translation of war fighter situations into policies which would feed into the network prioritization mechanism was explored. Third, a data and domain architecture in which to employ prioritization was developed. Finally, modeling and simulation of the network prioritization mechanism was conducted. It is recommended that the work that had been started in this project be continued and further developed by future Naval Postgraduate School masters and/or doctoral efforts.

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The report entitled "Ship-to-Shore Data Communication and Prioritization" was prepared for the Chairman of the Systems Engineering Department in partial fulfillment of the requirements for the degree of Masters of Science in Systems Engineering.

This report was prepared by the Masters of Science in Systems Engineering (MMSE) and Masters of Science in Engineering Systems (MSES) Cohort 3111-102W from Space and Naval Warfare Systems Command.

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ABSTRACT

Ships are plagued by connectivity issues while underway resulting in backlogs of data needing to get off a ship. This capstone project's main focus was to provide the Commanding Officer (CO) the capability to select and prioritize outgoing data flow from ship-to-shore dependent on their ship's operational situation while afloat. In carrying out this effort, the team focused its analysis on the Navy's Automated Digital Network System (ADNS) and Information Technology (IT) (i.e., shipboard networks and applications) communities. In so doing, the as-is technical status and current state of business processes were captured as a starting point for the work.

The team learned that the shipboard IT infrastructure, ADNS in particular, has the technical capability to prioritize data but that functionality is difficult to use and not widely understood by shipboard operators. As a result, most prioritization efforts are done ashore (instead of on the ship) which, in turn, puts extra work load on shore activities. The ADNS community is striving to make improvements in its Quality of Service (QoS) (prioritization of network traffic) and this effort is well underway. Although the technical infrastructure seems to be in place, the functional (user perspective) aspect of ship-to-shore data prioritization does not seem to be well organized and formed. This is probably one of the main reasons why data prioritization seems to be performed in a stove-pipe, fragmented, and ad-hoc manner, and conducted ashore instead of on the ship.

Thus, a framework providing a ship-to-shore data prioritization perspective from a systems point of view appears to be missing. This framework could bring the functional and technical aspects of data prioritization together. Accordingly, the team initiated the formulation of this framework in several ways. First, the team developed and introduced a conceptual prioritization matrix which would allow the CO to select and prioritize outgoing data based on the ship‟s operational situation. Second, the translation of war fighter situations into policies which would feed into the network prioritization mechanism was explored. Third, a data and domain architecture in which to employ prioritization was developed. Finally, modeling and simulation of the network

prioritization mechanism was conducted. It is recommended that the work that had been started in this project be continued and further developed by future Naval Postgraduate School masters and/or doctoral efforts.

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LIST OF ACRONYMS AND ABBREVIATIONS

AD	Air Defense
ADMIN	Administrative
ADNS	Automated Digital Network System
ANOVA	Analysis of Variance
AoA	Analysis of Alternatives
APM	Acquisition Program Manager
ASW	Anti-Submarine Warfare
ASUW	Anti-Surface Warfare
BW	Bandwidth
CBSP	Commercial Broadband Satellite Program
CBWFQ	Class Based Weighted Fair Queuing
C2	Command and Control
C4I	Command, Control, Communications, Computers, and Intelligence
C4ISR	Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance
C5I	Command, Control, Communications, Computers, Collaboration, and Intelligence
CENTRIXS-M	Combined Enterprise Regional Information Exchange System Maritime
CG	Guided Missile Cruiser
CJCSI	Chairman of the Joint Chiefs of Staff Instruction
CO	Commanding Officers
COI	Community of Interest
CONOPS	Concept of Operations
COP	Common Operational Picture
CT	Cipher Text
CTITF	Counter-Terrorism Implementation Task Force
CV	Capability View
DCA	Defensive Counter Air

DDG	Guided Missile Destroyer
DISA	Defense Information Systems Agency
DSCP	Differentiated Services Code Point
DoD	Department of Defense
DoDAF	DoD Architecture Framework
DON	Department of Navy
DNS	Domain Name Service
EHF	Extremely High Frequency
EMIO	Expanded Maritime Interception Operation
ENG	Engineering
FIFO	First In, First Out
FTP	File Transfer Protocol
GCCS-M	Global Command and Control System Maritime
HAIPE	High Assurance Internet Protocol Encryptor
HTTP	Hypertext Transfer Protocol (world wide web protocol)
IBS	Integrated Bar Code System
IDEF0	Integration Definition
IER	Information Exchange Requirements
INTEL	Intelligence
IP	Internet Protocol
IPT	Integrated Product Team
ISEA	In-Service Engineering Agent
ISNS	Integrated Shipboard Network System
IT	Information Technology
JCA	Joint Capability Areas
JCSFL	Joint Common System Function List
JCSS	Joint Communication Simulation System
JMS	Java Message Service
JTF	Joint Task Force
JTMD	Joint Theater Missile Defense
LAN	Local Area Network
LLQ	Low Latency Queuing

LOS	Line of Sight
LTE	Limited Technology Experiment
3M	Maintenance and Material Management
MAX	Maximum
MCM	Mine Countermeasures
MCT	Marine Corps Task
MED	Medical
MIO	Maritime Intercept Operations
MIN	Minimum
MOP	Measures of Performance
MSSE	Master of Science in Systems Engineering
MSES	Master of Science in Engineering Systems
MSG	Message
MSMQ	Multi-Server Multi-Queue
MTBF	Mean Time Between Failure
NATO	North Atlantic Treaty Organization
NCID	Net Centric Implementation Document
NCTAMS	Naval Computer and Telecommunications Area Master Station
NIAPS	Navy Information Application Product Suite
NIPRNET	Non-secure Internet Protocol Router Network
NOC	Network Operations Center
NPS	Naval Postgraduate School
NSFS	Naval Surface Fire Support
NSSA	Norfolk Ship Support Activity
NTA	Navy Tactical Task (Navy Mission Essential Task List)
NTCSS	Naval Tactical Command Support System
OPFACS	Operational Facilities
OPNET	Optimized Network Engineering Tool
OPS	Operations
OV	Operational View
PDA	Personal Digital Assistant

PEO	Program Executive Office
PEO C4I	Program Executive Officer, Command, Control, Communications, Computers and Intelligence
PMW	Program Manager, Warfare
PPP	Point-to-Point Protocol
PT	Page Table
PQ	Priority Queuing
PRI	Priority
QoS	Quality of Service
RF	Radio Frequency
RFC	Request for Comments
S&T	Science & Technology
SATCOM	Satellite Communications
SCI	Sensitive Compartmented Information
SCILAN	Scalable Coherent Interface Local Area Network
SHF	Super High Frequency
SIPRNET	Secret Internet Protocol Router Network
SME	Subject Matter Expert
SMTP	Simple Mail Transfer Protocol
SPAWAR	Space and Naval Warfare Systems Command
SPAWARSYSCENPAC	Space and Naval Warfare Systems Center Pacific
SSL	Secure Socket Layer
SubLAN	Submarine Local Area Network
SUW	Surface Warfare
SV	Systems View
SVDS	Shipboard Video Distribution System
TDL	Tactical Data Link
TMIP	Theater Medical Information Program
TS	Top Secret
TS/SCI	Top Secret/Sensitive Compartmented Information
TRL	Technology Readiness Level
TRNG	Training

UDP	User Datagram Protocol
UJTL	Universal Joint Task List
UML	Unified Modeling Language
UNTL	Universal Naval Task List
U.S.	United States
USN	United States Navy
VIP	Very Important Person
VIXS	Video Information Exchange System
VoIP	Voice over Internet Protocol
VTC	Video Teleconference
WAN	Wide Area Network
WRED	Weighted Random Early Detection

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EXECUTIVE SUMMARY

United States Navy (USN) ships are often plagued by poor connectivity while underway. Ship‟s connectivity is hampered by a number of external elements. For example, ships operating in the Arabian Gulf or other high concentration areas have to share limited satellite resources. As a result, ships are given small satellite connectivity windows during which time environmental factors such as heavy seas or adverse weather can cause periodic loss of connectivity. Furthermore, a ship‟s mission may sometimes necessitate a heading resulting in the mast or superstructure interfering with the direct line of sight between the antenna and satellite thus negatively impacting connectivity while this situation persists. Losses in connectivity on a regular basis result in a backlog of data waiting to get off the ship.

This capstone project's main focus was to provide the Commanding Officer (CO) the capability to select and prioritize outgoing data flow from ship-to-shore dependent on their ship's operational situation while afloat. In so doing, a more smooth, and orderly flow of information off the ship would be realized resulting in critical data getting where it is supposed to go in a timely fashion. The project team used a customized Classic Systems Engineering “Vee” model and concentrated on the left-hand side in order to analyze the problem and produce a conceptual solution. In addition to researching available technical literature, the team conducted stakeholder and needs analysis by participating in technical conferences and summits and interviewing experts in the field. The team focused its analysis on the Navy's Automated Digital Network System (ADNS) and Information Technology (IT) (i.e., shipboard networks and applications) communities. In so doing, the As-Is technical status and current state of business processes were captured as a starting point for the work.

The stakeholder and needs analysis resulted in a list of capabilities for this effort. These capabilities were then transformed into a set of high level requirements. The required capabilities were divided into two areas: user interface and prioritization mechanism. The user interface allows the user (i.e., CO, shipboard operators, etc.) to enter prioritization information into the system based on the ship's operational situation.

The prioritization mechanism translates the user-entered prioritization information into algorithms (or policies) that carry out the prioritization tasking.

The team learned that the shipboard IT infrastructure, ADNS in particular, has the technical capability to prioritize data but that functionality is difficult to use and not widely understood by shipboard operators. As a result, most prioritization efforts are done ashore (instead of on the ship) which, in turn, puts extra work load on shore activities. The ADNS community is striving to make improvements in its Quality of Service (QoS) (prioritization of network traffic) and this effort is well underway. Although the technical infrastructure seems to be in place, the functional (user perspective) aspect of ship-to-shore data prioritization does not seem to be well organized and formed. In other words, the "how" (solution) seems to have been built before clearly defining the "what" (what's needed by the war fighters). This is probably one of the main reasons why data prioritization seems to be performed in a stove-pipe, fragmented, and ad-hoc manner, and conducted ashore instead of on the ship.

Thus, a framework providing a ship-to-shore data prioritization perspective from a systems point of view appears to be missing. This framework could bring the functional and technical aspects of data prioritization together so that technology developers would not only build the solution right but also build the right solution for the war fighter.

The team initiated the formulation of this framework in this project in several ways. First, the team developed and introduced a conceptual prioritization matrix which would allow the CO to select and prioritize outgoing data based on the ship‟s operational situation. Second, the translation of war fighter situations into policies which would feed into the network prioritization mechanism was explored. Third, a data and domain architecture in which to employ prioritization was developed. Finally, modeling and simulation of the network prioritization mechanism was conducted.

In addition, the team recommended that the work that had been started in this project be continued and further developed by future Naval Postgraduate School masters and/or doctoral efforts. Future work could involve conducting a theater-wide stakeholder‟s functional requirements Integrated Product Team (IPT). This group would contribute elements from various war fighter user communities and elicit high level functional requirements from them. A user interface application could then be developed that would employ the prioritization matrix described in this project. This would give the CO the capability to select and prioritize data based on the ship‟s operational situation, before the data leave the ship. An automated interface service for the network could be developed to receive prioritization information from external application sources. An external application example would be the user interface described earlier. This service would translate the prioritization information from external application sources into QoS policies and other mechanisms to actually implement prioritization within the shipboard networks. Finally, a business process reengineering project could be performed. This capstone report conceives a system that eliminates the status quo in which prioritization is done mainly ashore and in an ad-hoc manner. In other words, prioritization would be done both aboard ship and ashore but would have to be consistent between them so as to maintain viable communication. Once prioritization can be fully implemented on the ship separately from shore, continuing to perform prioritization ashore could cause data conflicts as shore facilities get out of synchronization with shipboard activities. Therefore, a business process reengineering would be needed to mitigate this risk.

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As the SPAWAR Atlantic Capstone team, we would like to sincerely thank the Capstone advisors Professor J. Mike Green and Professor Weilian Su, PhD for the hours of guidance and support provided to the completion of this effort. These professors made tireless efforts to make sure that our research and applied skills were going down the proper path to completion.

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Special thanks to PEOC4I/PMW 160, specifically Delores Washburn and Alexander Vasel, for sharing knowledge and data provided on ADNS with regards to data transmission and operation.

We would like to say thank you to our sponsoring command SPAWARSYSCOM, SPAWARSYSCEN for the support provided during the duration of the MSSE and MSES programs. These programs were a great success to systems engineers by providing the funding, oversight, support staff, and connections to obtain this excellent opportunity to learn the theory of systems engineering of our practical day to day operations in providing the Navy the best engineering services that our abilities would allow.

The SPAWAR Atlantic Capstone team would like to express sincere thanks to everyone who provided assistance during this educational enlightenment period. If there were not significant strides made by family members, colleagues, and professors, this endeavor would not have been possible.

I. INTRODUCTION

United States Navy (USN) Ships are often plagued by poor connectivity while underway. Ship‟s connectivity is hampered by a number of external elements. For example, ships operating in the Arabian Gulf or other high concentration areas have to share limited satellite resources. As a result, ships are given small satellite connectivity windows during which time environmental factors such as heavy seas or adverse weather can cause periodic loss of connectivity. Furthermore, a ship‟s mission may sometimes necessitate a heading resulting in the mast or superstructure interfering with the direct line of sight between the antenna and satellite thus negatively impacting connectivity while this situation persists. Losses in connectivity on a regular basis result in a backlog of data waiting to get off the ship.

This capstone project's main focus was to provide the Commanding Officer (CO) the capability to select and prioritize outgoing data flow from ship-to-shore dependent on their ship's operational situation while afloat. In so doing, a more smooth, and orderly flow of information off the ship would be realized resulting in critical data getting where it is supposed to be in a timely fashion. A high level outline of this project is displayed in Figure 1. The case for action that impelled the project team to take on this work has been defined as follows: currently, there exists no means by which COs can prioritize outgoing data flow from ship-to-shore dependent on the ship‟s operational situation while afloat. As a result of this case for action, the ship-to-shore data communication project was conceived whose vision involves the development of a system that gives CO‟s the means to prioritize outgoing data flow dependent on ships‟ operational situations.

The main actors anticipated to be actively engaged in the operation of this system‟s processes include both COs, defined as any military person with the authority to design and carry out prioritization, and shipboard operators. Other key actors expected to benefit from operation of this system include the Program Executive Office for Command, Control, Communications, Computers, and Intelligence (PEO C4I), Space and Naval Warfare Systems Center Pacific (SPAWARSYSCENPAC), and the Norfolk Ship Support Activity (NSSA).

Ship to Shore Data Communication

Trigger Point	Sub-Processes			Results
Prioritization scheme requires changing because of changing mission.	Select appropriate operational situation	Select appropriate activity	Assign appropriate prioritization scheme	Prioritization scheme set based on ship‟s mission

Case for Action	Vision
Currently, there exists no means by which Commanding Officers (CO) can prioritize outgoing data flow from ship to shore dependent on their ship‟s operational situation while afloat.	The Ship to Shore Data Communication system gives Commanding Officers the means to prioritize outgoing data flow dependent on their ship‟s operational situation.

Actors	Mechanics	Metrics
Commanding Officers Shipboard Operators PEO C4I SPAWARSYSCEN PAC NSSA	- CO determines mission. - User interface allows entry of operational situation & mission. - Priorities established. - Types of data categorized & prioritized appropriately.	-Availability: 95-98% or more. - Reliability: MTBF > 2000 hours. - Usability: Operator Approval 80-90% or more. - Maintainability: Downtime < 1 hr. per event. - Efficiency: < 10% packet drop on average.

Figure 1. Process Definition

This figure provides the motivation behind the development of the ship-to-shore data communication system along with the system's high level attributes.

The trigger point of this system would be a mission change in the ship‟s activities that yields the need for changing data prioritization. In other words, the CO has selected a new mission for their ship, battle group, task force, etc. and that changing mission has resulted in changing data flow priorities. An onboard user interface then allows for the changing of those priorities. First, the ship‟s operational situation is selected (e.g., underway in theater). Next, the appropriate activity (mission) is chosen; anti-submarine warfare for example. Finally, based on the operational situation, activity, and other CO inputs, data priorities are established and the appropriate prioritization scheme is implemented. As a result, the changed prioritization scheme now represents that most conducive way in meeting the ship‟s current mission. From that point forward, all data flows will be categorized and prioritized based on this new prioritization scheme.

Proposed metrics for this system include availability, reliability (measured by Mean Time Between Failure (MTBF), usability, maintainability, and efficiency. The remainder of this paper describes the system in greater detail.

A. INITIAL PROBLEM STATEMENT

Currently, there exists no means by which a CO can prioritize outgoing data flow from ship-to-shore dependent on their ship‟s operational situation while afloat. Each software application communicating data with shore must come up with its own mechanism for transferring that data over the same satellite connection. As a result, when the ship‟s data connection is limited and/or unreliable, the ship creates a backlog of data requiring transmission to shore. This backlog congests the network and could result in the following: the inability to transmit necessary data that could affect the ship‟s mission (i.e., logistics data or message traffic); inhibited use of Secret Internet Protocol Router Network (SIPRNET) chat which is used for command and control coordination between other ships; and shore commands and delayed e-mail transmissions which could adversely affect ship‟s morale.

Additionally, the various data transfer mechanisms contain variations and inconsistencies between their respective methodologies and traffic load. Furthermore, little to no coordination takes place between mechanisms. These facts combined with the sheer number of data transfer mechanisms loading the ship‟s limited communication bandwidth pipeline, leads to the following issues: little to no chance for optimization or efficiency improvement; total sustainment costs multiplying with each additional mechanism, competition for the ship‟s communication resources; and no interoperability or sharing.

Communications mechanisms exist on board ships that utilize protocols, such as Simple Mail Transfer Protocol (SMTP), that are used by multiple applications resulting in a reduced reliability. Applications, like the Distance Support/ Navy Information Application Product Suite (NIAPS) file transfer procedures (flat file) result in unreliable and inefficient dissemination of data.

Although infrastructure such as Integrated Shipboard Network System (ISNS), Automated Digital Network System (ADNS), and Satellite Communications (SATCOM) is currently in place, they allow only for port closure to regulate the number of applications that can transmit off the ship. They currently provide no means for CO to set application priorities that would allow data transmission to occur in an efficient manner and ensures that the most prioritized applications have the earliest opportunity to reach their intended destinations.

B. CAPSTONE PROJECT PARTICIPANTS

The Capstone Project Team had as its members, ten students enrolled in the Naval Postgraduate School (NPS) Master of Science in Systems Engineering (MSSE) and Master of Science in Engineering Systems (MSES) program. The team was divided into the following sub-groups to focus on individual task.

Table 1. Capstone Sub-groups

Leader	Edgar C. Pontejos
Scheduler	Phillip Allen, Michael Brett Huffman
Librarian	Capstone Team
Architecture	Michael Brett Huffman, James W. Pinner, Michael J. Roderick
Modeling & Simulation	Phillip Allen, David P. Gravseth, Richard W. Hughes, Son Nguyen
Editors	Capstone Team
Stakeholders Analysis	Bradley J. May, Edgar C. Pontejos
Prioritization Matrix	Bradley J. May, Edgar C. Pontejos

The Capstone Project had several stakeholders and contributors. Their names are listed in the following table.

Table 2. Capstone Project Stakeholders and Contributors

Name	**Organization**
Mary Ellen Nies	PEO C4I (61610)
Delores Washburn	PEO C4I (616A0)
Alexander Vasel	SPAWARSYSCENPAC (56550)
Eric K. Otte	SPAWARSYSCENPAC (55130)
Richard L. Coupland	Naval Undersea Warfare Center (Code 25E)
Michael Morris	NAVCYBERFOR (N413)
Kevin Swann	NSSA
Floyd Fahie	NSSA
Doug Harding	NSSA

C. SYSTEM ENGINEERING PROCESS

This project used a customized Classic Systems Engineering "Vee" delineated in Figure 2. Beginning with the problem statement, the team researched the current customer wants and musts. In this context, the fleet is the main customer. Then, a needs analysis was conducted to match customer concerns with the problem statement which then established the domain (business activity) that the system supports. Encompassed within this domain are the needs, wants, and necessities that the customer perceived as problems. Following are the requirements elicited through stakeholder interviews, derived through research, and system analysis, which established the high-level system requirements. The requirements were then evaluated and further developed into a high-level system architecture which was closely tied to the system‟s requirements. Subsequently, a component conceptual design was formulated. Conceptual system alternatives to address the problem were developed. Modeling and simulation were conducted in order to evaluate system performance, conduct trade-off analysis, and compare the alternatives. Results and findings were then packaged as the recommended conceptual solution to the problem.

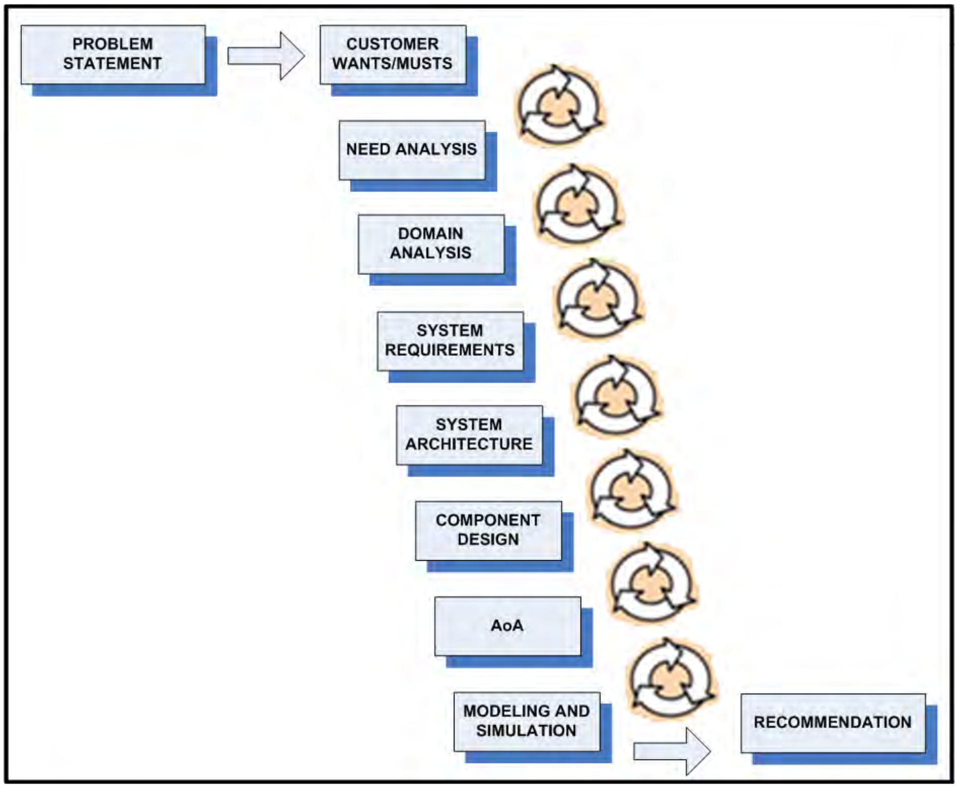


Figure 2. Classic Systems Engineering "Vee" (Custom Left-Side)

This is based on the standard Systems Engineering "Vee" model utilized in the engineering acquisition process in accordance with DoD 5000-2R.

D. CAPSTONE PROJECT SCOPE

The following defines the scope of this project:

- USN – analysis is within the boundaries of the USN;
- Limited Set of Operational Situations – only a selected set of sample operational situations and associated activities and data were used;
- Navy Ships – this project applies to afloat (ships) vessels only (i.e., submarines are out of scope);
- ADNS Enabled Navy Vessels – this project does not apply to Navy vessels that use ship-to-shore communication other than ADNS;
- Ship-to-shore – this project applies to ship-to-shore (one way) communication only;

- No ship to ship – ship to ship communication is out of scope;
- Outgoing Data – this project applies to outgoing data only (on ship data will not be addressed);
- Within Ship Only – analysis will be conducted within the ship only (e.g., SATCOM, shore Network Operations Centers (NOC) is out of scope);
- ADNS Enclave – this project applies within the ADNS enclave only (i.e., ISNS is out of scope); and
- Non-secure Internet Protocol Router Network (NIPRNET) – this project applies to NIPRNET only.

E. ASSUMPTIONS

Part of the scope of this project is limited to the system within the ship. In other words, the shore elements are not included as part of the scope. Therefore, this project assumed that there is some type of mechanism ashore to receive and process the prioritized data.

In simplifying the input data into the system, this project assumed that the data prioritization decision that has to be made by the CO could be reduced by the following criteria: operational situation, activity (or mission) type of data, and ranking of data. The prioritization matrix is based on this assumption.

It is assumed that once the process is underway that no other mechanism will interfere during and after the prioritization of the data. Otherwise, any form of interference could disrupt or even corrupt the prioritization of the data.

It is assumed that the network prioritization infrastructure (e.g., ADNS) either has or could have the capability (e.g., through modification if necessary) to receive prioritization information from external application sources.

F. BACKGROUND (BUSINESS AND INFORMATION TECHNOLOGY DOMAIN)

The domain of this project is comprised of two areas: business and Information Technology (IT).

The business domain is where ship personnel carry out their day-to-day tasking and processes. For example, personnel in charge of supplies perform inventory management, request, issue, processes and receive materials. Medical personnel may see patients and carry out tasking such as providing immunizations. The CO in turn may select data and prioritize them (depending on the operational situation) to send to shore. All these happen within the business domain. In this project, the term “CO” is generic. The “CO” is any military person who has the authority to decide and carry out prioritization.

The IT domain is the technology infrastructure that supports the business domain. Technology (hardware and software) is used to facilitate and automate business processes. For example, Integrated Bar Code System (IBS) and Naval Tactical Command Support System (NTCSS) are applications that are used in supply processes. The Theater Medical Information Program (TMIP) is a suite of medical software that is used in medical information environment. Software is hosted in hardware computer systems such as Personal Digital Assistants (PDA), workstations, and/or servers. These computer systems are interconnected to each other through networks so that they can store, exchange data with each other, or send data off ship to the shore. All these happen within the IT domain. Figure 3 illustrates this IT infrastructure in general terms.

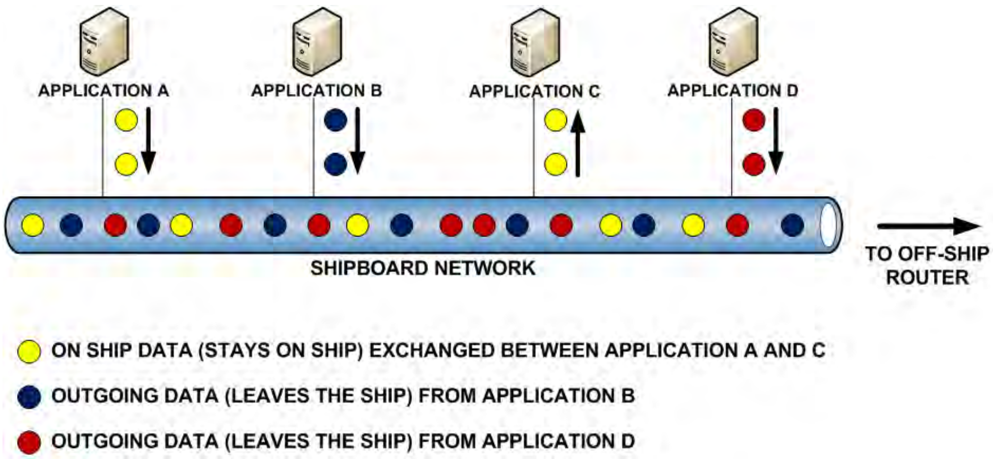


Figure 3. IT Infrastructure

This IT domain infrastructure supports the ship's business processes that occur in the business domain.

In Figure 3 above, Application A could be the supply software IBS and Application C could be NTCSS. These two supply applications communicate data with each other but the data may stay on the ship only (although NTCSS data could be sent off-ship). Application B could represent TMIP and Application D could represent additional software that sends data off the ship.

The following sections break these domains down in more details.

1. Business Domain (Operational Situations and Activities)

A ship may be in one of several possible operational situations. For example, it may be underway in theater or it may be underway in transit. The following are examples of operational situations: underway in theater, underway in transit, homeport, United States (U.S.) port (other than homeport), foreign port, and dry docked.

Associated with each operational situation are activities (or missions). For example, while in the underway in theater operational situation, the ship may be engaged in Air Defense (AD) or strike activity. The following are examples of activities: AD, Joint Theater Missile Defense (JTMD), strike, Naval Surface Fire Support (NSFS), Maritime Intercept Operations (MIO), Mine Countermeasures (MCM), Antisubmarine Warfare (ASW), Surface Warfare (SUW), Intelligence Collection (INTEL), Humanitarian Operations, and Off Station.

Ship business processes such as supply and medical generate data that could be tied to activities (or missions). Other day to day business activities also produce data such as e-mail, video, and voice data. The following are examples of business processes data: video, voice, chat, critical e-mail (i.e., that sent by users and/or roles deemed critical), medical, engineering, Maintenance, and Material Management (3M) data, administrative, operations, message traffic, training, non-critical e-mail, web browsing.

Depending on the ship"s operational situation, some of the business process data may be relevant to a particular activity (or mission). In addition, some of the data may be more important than others. Shore commanders may have a need for such data to conduct maritime operational planning, for example, and the ship CO must select and prioritize them accordingly before they leave the ship. According to Kevin Dugan's thesis, "Navy Mission Planner" [Naval Postgraduate School, September 2007],

"Maritime operational planners continuously address the complex problems involved with the employment of Navy ships. The assignment of ships to missions must take into account ship capabilities, the time each ship is available in theater, distances and transit times between missions, and mission values. This complicated and multifaceted staff task has been accomplished up to this point largely through manual planning efforts. In regards to the number of maritime missions and their geographic dispersion in any major operation, Navy ships continue to be in short supply. Surface and subsurface combatants are called upon to cover more missions and more geographic areas than is possible with ships that are available."

Therefore, it is important for the ship CO to have the capability to select and prioritize data before the data leave the ship in order to provide information to maritime operational planners and to support other naval situational awareness and decision support needs.

2. IT Domain (The Shipboard Network Architecture)

The USN deploys large, enterprise-scale Local Area Networks (LANs) aboard their ships. LANs simply represent collections of computers, printers, and other devices connected by some form of communication channel (wired or wireless). This setup allows users to communicate and share resources with other users. USN LANs are organized into a client-server relationship. Clients are merely the workstations and other peripheral devices that the sailors use. Servers are powerful computers running specialized software that allows them to "serve" information requests from the clients. Examples of information requests include sharing files or other data, running e-mail systems or websites, and hosting applications for client usage.

Different sections of the network such as clients and servers that are connected to one another are often referred to as nodes. Nodes communicate with each other via switches. Switches are hardware components that control information flow between nodes. In other words, switches enable data transmission from one node (the source node) to the specific node for which the data was intended (the destination node) while bypassing all the other nodes on the network. This greatly speeds up data transmission in a network.

Typical USN ships contain not one but many networks. When data is exchanged between networks, this communication is facilitated by use of a router. The router represents another piece of sophisticated network equipment, like the switch. Unlike the switch, however, the router handles information flow between networks as opposed to information flow between nodes on the same network. In other words, any time data must be transmitted between two networks, routers tell the data where to go and how to get there.

Lastly, a modem (modulator/demodulator) takes the digital signals being transmitted over the LAN and converts them into analog signals appropriate for transmission off the ship through a satellite, Extremely High Frequency (EHF), or other communication channel. The modem either interacts with the router or is integrated into it. USN ships use a specialized piece of equipment called the ADNS. This is a router integrated with a modem that allows shipboard networks to communicate off the ship. It provides Internet Protocol (IP) connectivity from ship-to-ship or ship-to-shore by efficiently using whatever bandwidth the ship has available.

A basic shipboard LAN configuration is displayed in Figure 4. Different nodes on the network such as workstations, servers, printers, etc. are connected to one another via switches. This simple network is further connected to other shipboard networks or to off-ship communication channels via a router. ADNS represents the pathway off the ship.

As previously mentioned, USN ships contain many different networks. The primary ones include ISNS, Submarine Local Area Network (SubLAN), Combined Enterprise Regional Information Exchange System Maritime (CENTRIXS-M), Global Command and Control System Maritime (GCCS-M), Scalable Coherent Interface Local Area Network (SCI LAN), NTCSS, and Video Information Exchange System and Shipboard Video Distribution System (VIXS/SVDS). These will now be described in a bit more detail.

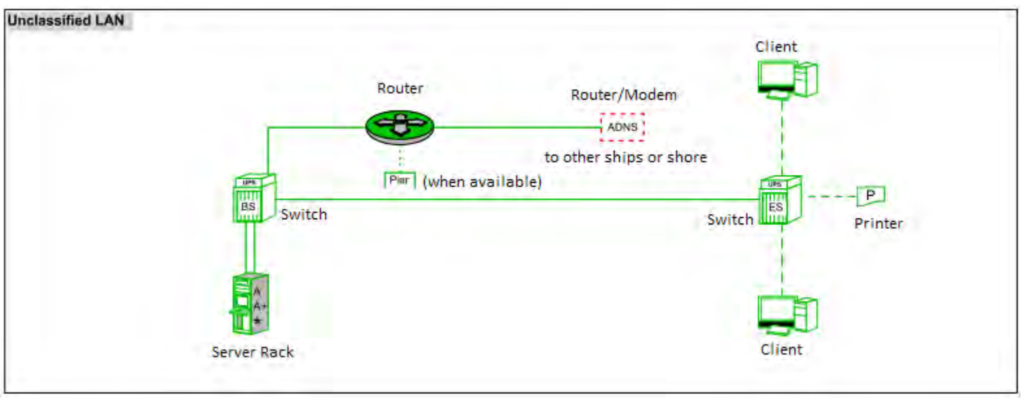


Figure 4. Basic Shipboard LAN

High level diagram of a typical shipboard LAN. [From PMW 165, 2001].

ISNS is a system of hardware and software that, taken together, forms the legacy network infrastructure on surface ships throughout the fleet. Through separate hardware, it can handle all classification levels from Top Secret to Unclassified. SubLAN is essentially the submarine version of ISNS. CENTRIXS-M provides secure operational and tactical information sharing between the U.S. and coalition maritime partners. These partners consist of seven different allied groups including Japan, South Korea, the North Atlantic Treaty Organization (NATO), and the Counter-Terrorism Implementation Task

Force (CTITF). GCCS-M receives, displays, correlates and maintains geographic location data. This data is integrated with intelligence and other environmental information to arrive at a tactical picture. SCI LAN provides a separate network for transmission and receipt of special intelligence. It operates at the Top Secret/ Sensitive Compartmented Information (TS/SCI) level of clearance. NTCSS is a group of software applications that allows the ship"s CO and crew to manage maintenance of equipment, parts inventory, finances, automated technical manuals, personnel data, medical information, etc. VIXS/SVDS supports video exchange, streaming video distribution, and Video Teleconferences (VTC).

G. THE CURRENT STATE OF ADNS (AS-IS)

ADNS Increment III represents the newest version of ADNS and is currently deployed on nine ships. Plans call for the outfitting of the fleet (about 200 ships) with ADNS Increment III over the next ten years. From this point forward, any reference to ADNS means ADNS Increment III unless otherwise specified. A picture of an ADNS terminal is shown in Figure 5.

Figure 5. Typical Shipboard ADNS Terminal

Picture of a shipboard rack containing the ADNS terminal [From USN, 2011].

Figure 6 depicts a high-level diagram of ADNS and the systems with which it interacts. As previously noted, ADNS consists of a router integrated with a modem that allows shipboard networks to communicate off the ship. It serves as the information routing center distributing data between shipboard networks and the available Radio Frequency (RF) pathways off the ship. There are several key points illustrated in Figure 6, first, ADNS handles data at different classification levels. Second, in addition to data, ADNS also bears responsibility for voice and video transmissions. Last, ADNS manages available bandwidth to ensure that data travels off the ship on the most appropriate and efficient path.

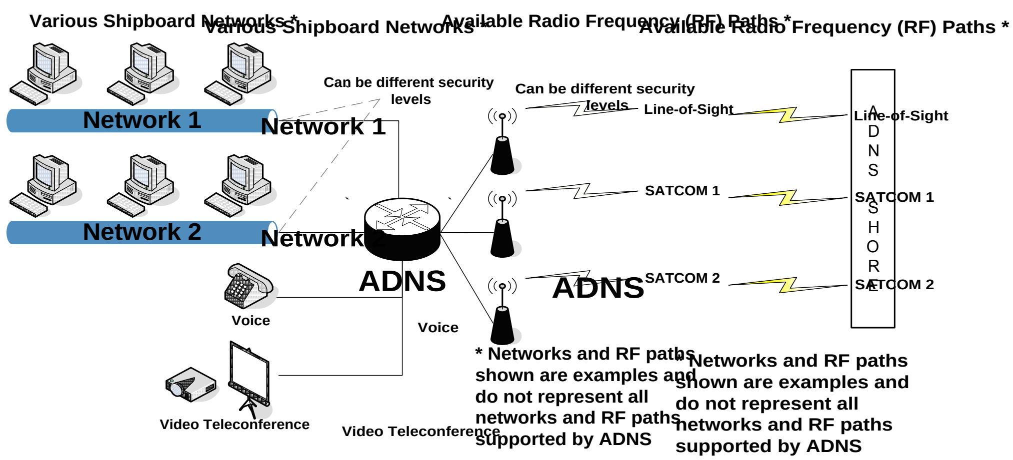


Figure 6. ADNS High-Level Diagram

Depicts how ADNS routes data from various shipboard networks to shore facilities [From K. Shah, 2011].

Since all data traveling off the ship must pass through ADNS, it acts as a system bottleneck. At any bottleneck, Quality of Service (QoS) becomes important. QoS is what allows the network to make smart decisions when available resources cannot keep up with network traffic loading. Without QoS, all network traffic going off the ship must compete for limited bandwidth. This could lead to mission-critical data getting delayed or dropped and not reaching its destination in a timely fashion. With QoS, higher priority network traffic receives a greater share of network resources than lower priority traffic. This ensures that network traffic is delivered as expeditiously and efficiently as possible while also maximizing network bandwidth utilization. ADNS ensures that data, voice, and video are routed efficiently by managing and optimizing the use of RF resources. It does this by classifying different applications and routing them into queues based on that classification. Each queue is then guaranteed a certain bandwidth based on the marking of data packets within that queue.

Figure 7 displays a more detailed diagram of ADNS and other interoperable systems. The blocks labeled Communities of Interest (COI) depict areas that represent various shipboard networks operating at different security classification levels. The figure also shows data, Voice over IP (VoIP), and VTC riding across these networks and applications such as joint communications activity and Tactical Data Link (TDL) broken out separately in the Secret domain. However, these are of little concern to the remainder of this paper and will not be discussed further. Each COI passes data through a router which is often referred to as an edge router since it resides at the outer edge of its respective network. This router is analogous to the router upstream of ADNS shown in Figure 4.

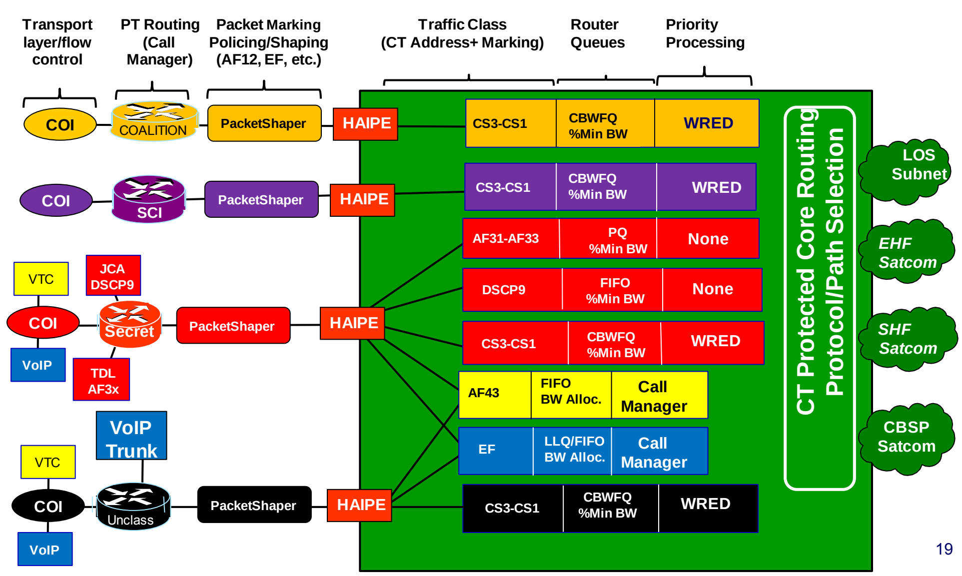


Figure 7. ADNS Detailed Diagram

Detailed depiction of how data from different shipboard networks of various classification levels travel through ADNS to the ship's RF infrastructure [From K. Shah, 2011].

From the edge router, data packets then enter a packet shaper. This device marks or classifies the packets. It does this by assigning a Differentiated Services Code Point (DSCP) marking to each data packet. Figure 8 shows how DSCP marking works. Each packet contains a type of service field. Six bits of this field are used to assign a DSCP marking to each packet. Thus, 26 or 64 different markings could be assigned to the packet. This marking is then used to provide QoS in the network. The packet shaper identifies the specific application that generated the packet and then marks the packet accordingly. Table 3 lists all the applications currently getting assigned QoS markings by ADNS.

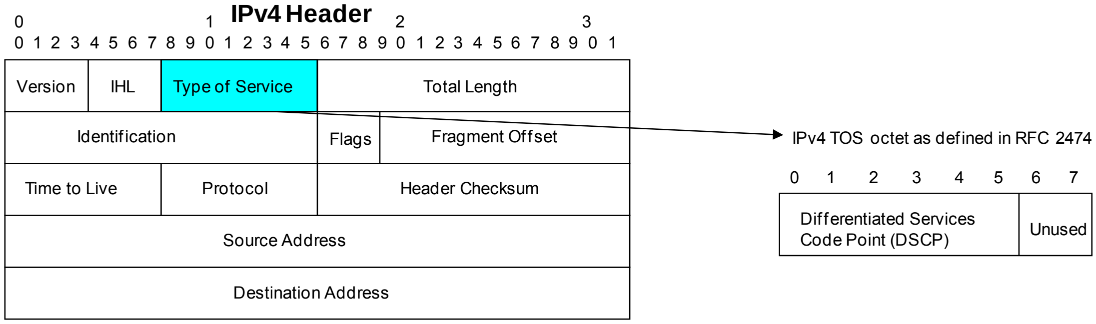


Figure 8. Differentiated Service Code Point (DSCP) Marking

Displays how the type of service field within a data packet's header can be used to classify that packet into a certain data category [From K. Shah, 2011].

Table 3. Applications Assigned QoS

Application	Assigned how	Assigned by
VTC	specifically	IP address
EMIO	specifically	IP address
RAPIDS	specifically	IP address
Navy Cash	specifically	IP address
JCA	specifically	IP address
GCCS-M	specifically	ports
MTJ	specifically	ports
Critical web (.mil, .edu, .gov, SSL)	generally	ports & protocols
E-mail (SMTP)	generally	ports & protocols
Web (HTTP)	generally	ports & protocols
FTP, etc.	generally	ports & protocols

Applications currently getting assigned QoS markings by ADNS.

From the packet shaper, marked packets then pass through cryptographic equipment (High Assurance Internet Protocol Encryptor (HAIPE)). From there, the encrypted packets go into ADNS and are routed to specific queues based on their DSCP markings from the packet shaper. Table 4 lists different types of applications, how ADNS currently marks them in the packet shaper, and how they are subsequently routed into a queue.

Table 4. Application Types, Marking, and Queuing

Baseline CBWFQ MIN/MAX Queue Size and Drop Probability for Traffic priorities

	Application or Traffic Types in priority Order	DSCP	Class	Queue Type	WRED			
					MIN Queue Size	MAX Queue Size	Drop Prob	1/ Drop Prob
	Routing Overhead	48	CS6	CBWFQ	99	100	100	
Real time Inelastic	Interactive Voice	46	EF	LLQ				
	Video	38	AF43	FIFO				
	Reserved for High Priority UDP	26	AF31	FIFO	NA	NA	NA	
	Reserved for Medium Priority UDP	28	AF32	FIFO				
	Reserved for Low Priority UDP	30	AF33	FIFO				
Preferred Elastic	Reserved for high priority applications	24	CS3	CBWFQ	32	60	16	6.3%
	Reserved for Fires, etc.	18	AF21	CBWFQ	28	56	15	6.7%
	Chat, DNS	20	AF22	CBWFQ	26	52	14	7.1%
	GCCS-M NETPREC, Critical E-mail / Web/CST	22	AF23	CBWFQ	24	48	13	7.7%
	JCA	9		FIFO				
	Whiteboard, Web	10	AF11	CBWFQ	18	36	12	8.3%
	Email	12	AF12	CBWFQ	16	32	11	9.1%
	Bulk Data (FTP)	14	AF13	CBWFQ	14	28	10	10.0%
Elastic	Default	0	CS0/BE	CBWFQ	12	24	9	10.1%
	Scavenger (Oracle, CaS, TBMCS)	8	CS1/LE	CBWFQ	10	20	8	12.5%

Different types of applications, how ADNS currently marks them in the packet shaper [From K. Shah, 2011]

The ADNS cipher text router (cipher text because it is on the encrypted side of the HAIPE) reads the DSCP marking of each packet and separates them into queues accordingly. Per Table 4, three queue types exist: First In First Out (FIFO), Low Latency Queuing (LLQ) essentially priority queuing, and Class Based Weighted Fair

Queuing (CBWFQ). FIFO and LLQ are used for applications providing real-time services (e.g., video and voice) and for applications providing very high priority traffic. Further discussion of these two queue types in the remainder of this paper is minimal. They were not pertinent to the problem of interest. However, the CBWFQ queue type is relevant.

CBWFQ provides a method of defining different classes of data traffic based on some criteria. DSCP markings represent the criteria ADNS uses to define traffic classes in shipboard networks. Different applications are assigned DSCP markings based on IP addresses, ports, and protocols. Packets with the same DSCP markings get routed to the same queue. Each queue then has a certain amount of bandwidth applied to it. Queues containing what are considered to be higher priority packets will get more bandwidth assigned than those queues filled with what are considered to be lower priority packets. If a queue gets too full, then the lower priority packets get dropped. This method is referred to as Weighted Random Early Detection (WRED) and it creates a means to avoid network congestion while ensuring that higher priority packets pass off the ship. This process is diagrammed pictorially in Figure 9.

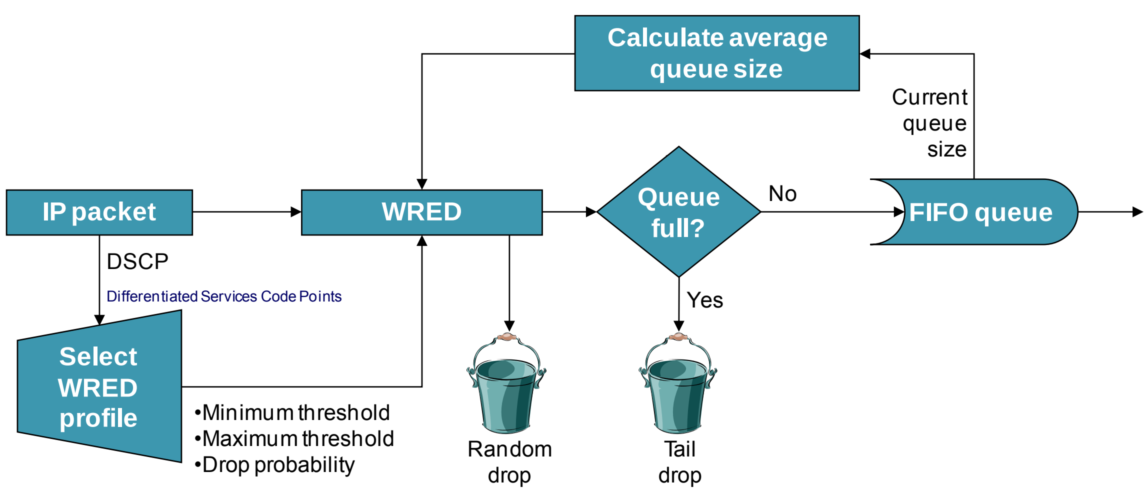


Figure 9. Weighted Random Early Detection

Basic flowchart showing implementation of the WRED process [From K. Shah, 2011].

Per Figure 9, minimum and maximum queue size thresholds are set along with a packet drop probability. The average queue size is calculated. When the minimum threshold is exceeded in a queue, lower priority packets are randomly dropped based on the drop probability entered. If the maximum threshold is exceeded in a queue, then packets at the tail of that particular queue begin getting dropped as well.

In addition to the QoS methodologies previously discussed, ADNS uses two other means to improve network throughput. These are compression and acceleration. Compression shrinks the size of certain packets to improve overall network capacity. However, some packets are non-compressible, such as voice, video, Secure Socket Layer (SSL), joint communications activity, GCCS-M, and others. Acceleration helps to speed up any application performance that has been slowed by latency across the wide area network (WAN).

Although ADNS represents significant improvements over prior versions of ADNS, there still exist other improvement features that could be added. For example, ADNS can allow up to 64 queues to be used based on DSCP markings. However, not all 64 are currently used. That leads to the possibility of generating more granularity in the way applications are classified, marked, and subsequently prioritized. Thus, more applications can be differentiated from one another in terms of their individual priority relative to the mission at hand. This leads to a need to define what applications are critical based on the particular mission. If different applications have different priorities based on mission, then this relates back to the need mentioned in the initial problem statement of CO having the ability to prioritize outgoing data flow from ship-to-shore dependent on their ship"s operational situation while afloat. There are two ways to change prioritization given the current construct of ADNS. One, when application priorities need to change, change the markings on those application"s packets. This would then change the queue to which they get routed such that higher priority packets go to queues with higher bandwidth allocation and vice-versa. Two, change each queue"s bandwidth allocation so that higher bandwidth gets allocated to queues containing packets with higher priorities and lower bandwidth gets allocated to queues containing lower priority packets.

II. PROBLEM REFINEMENT AND NEED ANALYSIS

Community areas were approached for stakeholder representation and definitive requirements for the validation that the Capstone project was on a path to provide a useful engagement of the subject to add value. Stakeholder identification and agreement was of the utmost importance in project definition to make sure the project would provide valuable benefit to the progress being made in areas of research. Once the stakeholders were identified, a focused effort was utilized to identify the real life areas of requirements for improvement that research would provide the most benefit back to the end user, stakeholders, and overall community.

A. STAKEHOLDERS AND NEEDS ANALYSIS

Stakeholders and needs analyses were accomplished through research, reviewing literature, interview of stakeholders by team members, and through participation in conferences, summits, and technical working groups.

During the Fleet Stakeholders Conference that was held in Norfolk, Virginia, in June 2011, the panel of flag officers delivered several messages to an audience comprised of mainly technology providers. They gave the technology providers what they perceived as the fleet‟s "wants and musts". They challenged the technology providers to deliver capabilities faster, at reduce costs, and avoid proprietary products (i.e., use open source). In addition, they asked technology providers to strive for the following: compatibility, interoperability, reduced interference (including protection from cyber attacks), Common Operating Picture (COP), and Commander‟s priority (on/off ship).

Clearly from the above, providing the CO with the capability to prioritize is a "very real subject to address", as a Science and Technology (S&T) assistant program manager Subject Matter Expert (SME) had said in an interview during the stakeholders analysis.

According to a PEO C4I ADNS Acquisition Program Manager (APM), during the stakeholders analysis, there is an increasing demand from some fleet operators for more granular control of QoS, i.e., prioritization of network traffic. However, it needs to be balanced with the reality of manning levels both on the ship and at the shore nodes and their workload. Shore sites (i.e., Naval Computer and Telecommunications Area Master Station (NCTAMS) / NOCs) have a very demanding job just keeping all connectivity up with the ships in their respective theatres. These sites should not have to respond to individual, ad-hoc changes in QoS for each ship because that would be unmanageable, at least with the technology available today.

The ship"s ADNS has the capability to prioritize outgoing data but this capability is not fully utilized. According to interviews with SMEs, any current prioritization programming is not generally done by the ship's force. It's done by the SMEs at the In-Service Engineering Activity (ISEA). In the words of one SME, the ship's force has the capability to change priorities but don't really know they have that capability. If prioritization is not done correctly, it can lead to an unbalance network that can increase congestion as certain queues constantly fill up. That can lead to critical messages not getting off the ship or the network going down completely. One reason why it's so hard for the ship's force to change priorities is because the ADNS technology to employ the capability is not yet fully mature and is lacking certain key elements such as a data marking standard that all related technologies could follow.

One of the participants from the September 2011 QoS Technical Summit commented that this effort is really about translating war fighter situations into policy and expressed the need to have a framework developed for articulating war fighter-driven policy. This same thought was shared by participants in the September 2011 "Multi-Service Limited Technology Experiment (LTE) Very Important (VIP) Day." Another SME suggested changing the data markings and/or changing the queuing to implement different policies in the network. That is, establish a static but well planned queuing structure and change markings as needed to effect policy changes.

B. REFINED PROBLEM STATEMENT

The initial problem statement of this effort changed slightly as the team learned more information through its research. The focus remained the same which was to provide the CO the capability to select and prioritize outgoing data flow from ship-to-shore dependent on their ship‟s operational situation while afloat.

The team learned that the shipboard IT infrastructure, ADNS in particular, has the technical capability to prioritize data but it is difficult to use and not widely known. Although this capability is not widely used and needs improvement, it exists. However, the functional (user perspective) aspect of ship-to-shore data prioritization doesn't seem to be well organized and formed. This is needed in order to drive the technical prioritization capability which ADNS provides. In other words, the "how" (solution) exists but the "what" (what's needed) seems to be cloudy. In fact, prioritization seems to be performed in a stove-pipe, fragmented, and ad-hoc manner. As a result, most prioritization efforts are done ashore which in turn puts extra work load on shore activities. What seems to be missing is a framework which would be a ship-to-shore data prioritization perspective from a systems point of view. This framework should bring the functional and technical aspects together and help bring back the prioritization effort to the ship where it belongs instead of having it done ashore.

The team focused this project on initiating this framework, as recommended by some of the stakeholders. The technical aspect of data prioritization is pretty much in place. The Navy's ADNS and IT community is well underway in making improvements and trying to standardize its prioritization capability, along with making network improvements to address backlogs and traffic congestions. Rather than addressing these subjects directly and duplicating ADNS' effort, the team paralleled its modeling and simulation work with what the ADNS community is currently exploring and focused on the prioritization aspect, that is, improvements in data marking, queuing, and QoS.

The team focused its effort in establishing the conceptual framework for the ship-to-shore data prioritization by:

- Developing and introducing a conceptual prioritization matrix which would allow the CO to select and prioritize outgoing data based on the ship‟s operational situation;

- Exploring the translation of war fighter situations into policy which would in turn feed into the network prioritization mechanism;
- Developing a data and domain architecture in which to employ prioritization; and
- Modeling and simulating the network prioritization mechanism.

C. CONCEPT OF OPERATIONS

The CO needs the ability to deliver critical, time-sensitive information from their ship to other ships or to shore whenever required. The primary mission of the Ship-to-shore Data Communication system gives the CO the means to prioritize outgoing data flow dependent on their ship‟s operational situation. A secondary mission yields better congestion management of unclassified packets so as to minimize network congestion thus facilitating more smooth and orderly flow of critical information off the ship.

A high level flowchart of how the system will operate is displayed in Figure 10. This system concerns itself exclusively with unclassified shipboard networks and applications. Unclassified packets generated at the start of the flowchart must first be categorized in accordance with some categorization criteria. This could be port number, application type, source address, source-destination pair, or some other criteria.

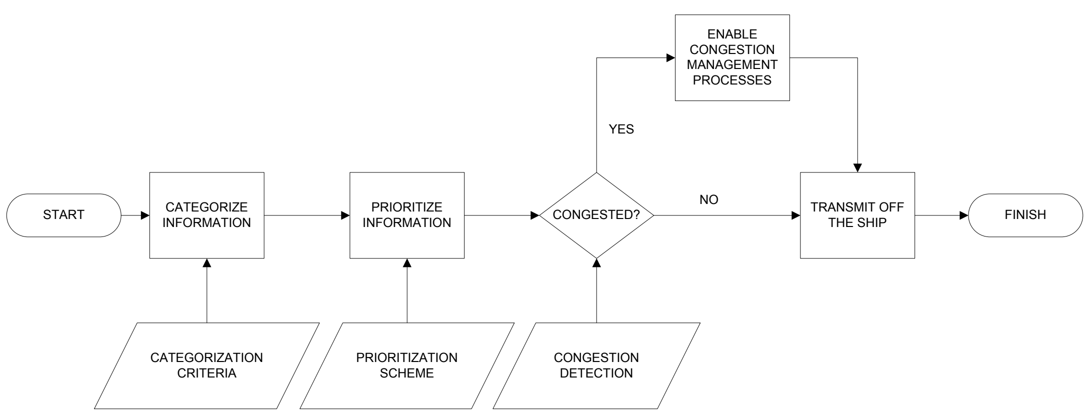


Figure 10. Ship-to-shore Data Communication System Flowchart

Flowchart describing how the basic Ship-to-shore Data Communication system process will function.

Next, each categorized packet must be prioritized according to some prioritization scheme. It is this prioritization scheme that the system will provide the flexibility for CO to change based on their ship"s operational situation. Potential operational situations would include the following: underway in theater, underway in transit, homeport, U.S. port (other than homeport), foreign port, and dry docked. Only the underway in theater operational situation will be considered for this Concept of Operations (CONOPS). It is this situation for which a variety of activities (or missions) could be assigned that would cover the full range of military operations of interest. The other operational situations have no activities of interest associated with them and, as such, are left for further research rather than being considered in this CONOPS. Potential assigned missions for the underway in theater operational situation are listed in Table 5 along with a brief description of each. Prioritization data would be entered into the system via a user interface in accordance with entries made in a prioritization template much like that shown in Table 6. In Table 6, the activities are given in the columns while the rows contain the different business processes requiring prioritization. Each cell in the template would contain some kind of prioritization number relating the priority of each business process to each specific activity. For the purposes of this CONOPS, the following two assumptions were made regarding the business processes listed in Table 6. First, video, voice, chat, and critical e-mail will always possess the highest priority. Second, non-critical e-mail and web browsing will always be assigned the lowest priority. Thus, only the middle seven business processes will be analyzed further in this research. These seven business processes include medical, engineering, 3M, administrative, operations, message traffic, and training which are the regions of interest for the reminder of the paper.

Table 5. Mission Types and Descriptions

Mission Type	Description
Air Defense (AD)	All defensive measures designed to destroy attacking enemy aircraft or missiles.
Joint Theater Missile Defense (JTMD)	The integration of joint force capabilities to destroy enemy theater missiles in flight or prior to launch or to otherwise disrupt the enemy‟s theater missile operations.
Strike	An attack which is intended to inflict damage on, seize, or destroy an objective.
Naval Surface Fire Support (NSFS)	Fire provided by Navy surface gun and missile systems in support of a unit or units in the field.
Maritime Interception Operations (MIO)	Efforts to monitor, query, and board merchant vessels in international waters to enforce sanctions against other nations.
Mine Countermeasures (MCM)	All offensive and defensive measures for countering a naval mine threat.
Anti-Submarine Warfare (ASW)	Operations conducted with the intention of denying the enemy the effective use of submarines.
Surface Warfare (SUW)	Operations conducted to destroy or neutralize enemy naval surface forces and merchant vessels.
Intelligence Collection (Intel)	The acquisition of information and the provision of this information to processing elements.
Humanitarian Operations	Disaster relief, goodwill visits, etc.
Off-Station	The disposition of a ship when it is in a region, but it is unavailable for any of the missions previously defined.

Table 6. Prioritization Matrix Example Template (Underway in Theater)

UNDERWAY IN THEATER	Air Defense (AD)	Joint Theater Missile Defense (JTMD)	Strike	Surface Fire Support (NSFS)	Maritime Intercept Operations (MIO)	Mine Countermeasures (MCM)	Antisubmarine Warfare (ASW)	Anti-Surface Warfare (ASUW)	Intelligence Collecton (INTEL)	Humanitarian Operations	Off Station
Video	High	High	High	High	High	High	High	High	High	High	High
Voice	High	High	High	High	High	High	High	High	High	High	High
Chat	High	High	High	High	High	High	High	High	High	High	High
Critical E-Mail	High	High	High	High	High	High	High	High	High	High	High
Medical											
Engineering											
3M											
Administrative											
Operations											
Message Traffic											
Training											
Non-Critical E-Mail	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low
Web Browsing	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low	Low

REGION OF INTEREST

A user interface is needed to allow the CO the ability to enter in the prioritization data. A high-level Unified Modeling Language (UML) class diagram representing this potential user interface is displayed in Figure 11. The appropriate operating situation and activity (mission) are chosen by the user. This leads to the generation of a lookup code allowing the correct prioritization values to be pulled from the prioritization matrix. These prioritization values are pulled based on operating situation and activity and aligned with their respective business processes into a corresponding priorities array. This array of prioritization data is then transferred across the user interface boundary to the other related shipboard systems. In this way, packets can be prioritized correctly based on the ship‟s operational situation and assigned mission.

The entire process can be summarized by the swim lane diagram of Figure 12. Three major roles are considered essential to entering in the appropriate data and making the prioritization matrix a reality. First, the CO, as previously discussed, refers to a generic responsibility. This responsibility includes the authority to set the mission and establish appropriate priority levels for packets based on that mission. Examples of CO‟s would be battle group commanders, task force commanders, or the captains of ships deployed on independent operations. Second, the platform user represented by any individual onboard a ship or other platform that has the responsibility to make changes to the system through the user interface. Third, the platform authorizer who has the authority to verify that any changes to the system via the user interface were made correctly and were in accordance with the CO‟s directives.

Once packets have been categorized and prioritized, the next step involves determining whether or not congestion exists in the network. Thus, some kind of congestion detection mechanism must exist to make this determination. This mechanism could include techniques such as monitoring queue sizes, measuring output line usage of key network devices, monitoring round-trip delay times, using a source probing scheme to determine network state, or setting a timeout for package acknowledgement.

When no congestion exists on the network, packets can be sent off the ship without engaging any sort of congestion management regime. However, they still will be sent off the ship based on the prioritization scheme in use. This will be based on some method of fair queuing that would ensure all packets receive a fair share of the available bandwidth based on their priority. This would hopefully minimize the amount of congestion realized thus keeping the necessity of implementing congestion management procedures to a small fraction of total network uptime. In the instances when congestion does exist, then certain congestion management processes will be initiated. These could include such things as source throttling, source quench, or packet dropping.

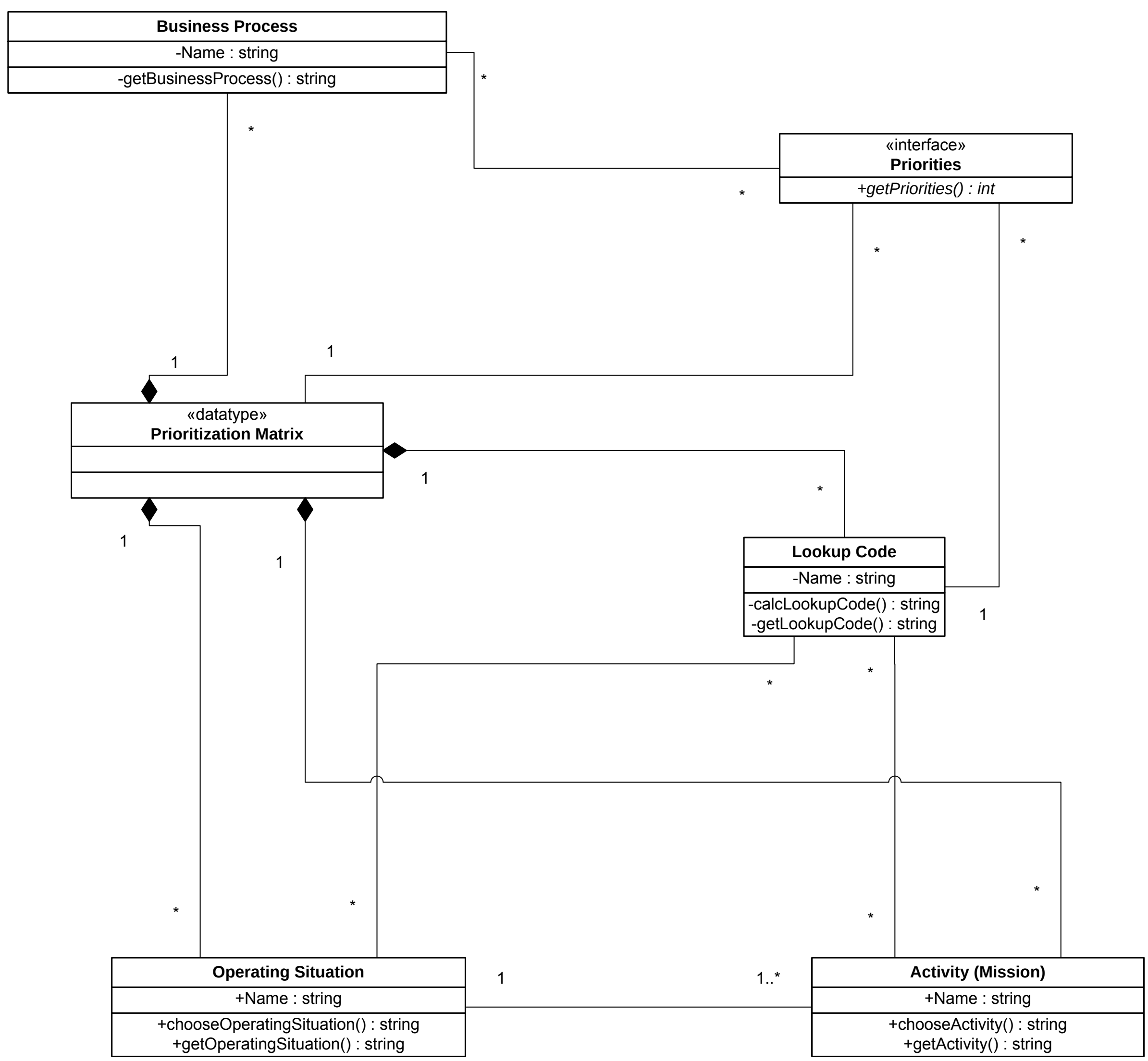


Figure 11. Ship-to-shore Data Communication System Class Diagram

Shows the static structure of notional software architecture for potential use in the system's user interface.

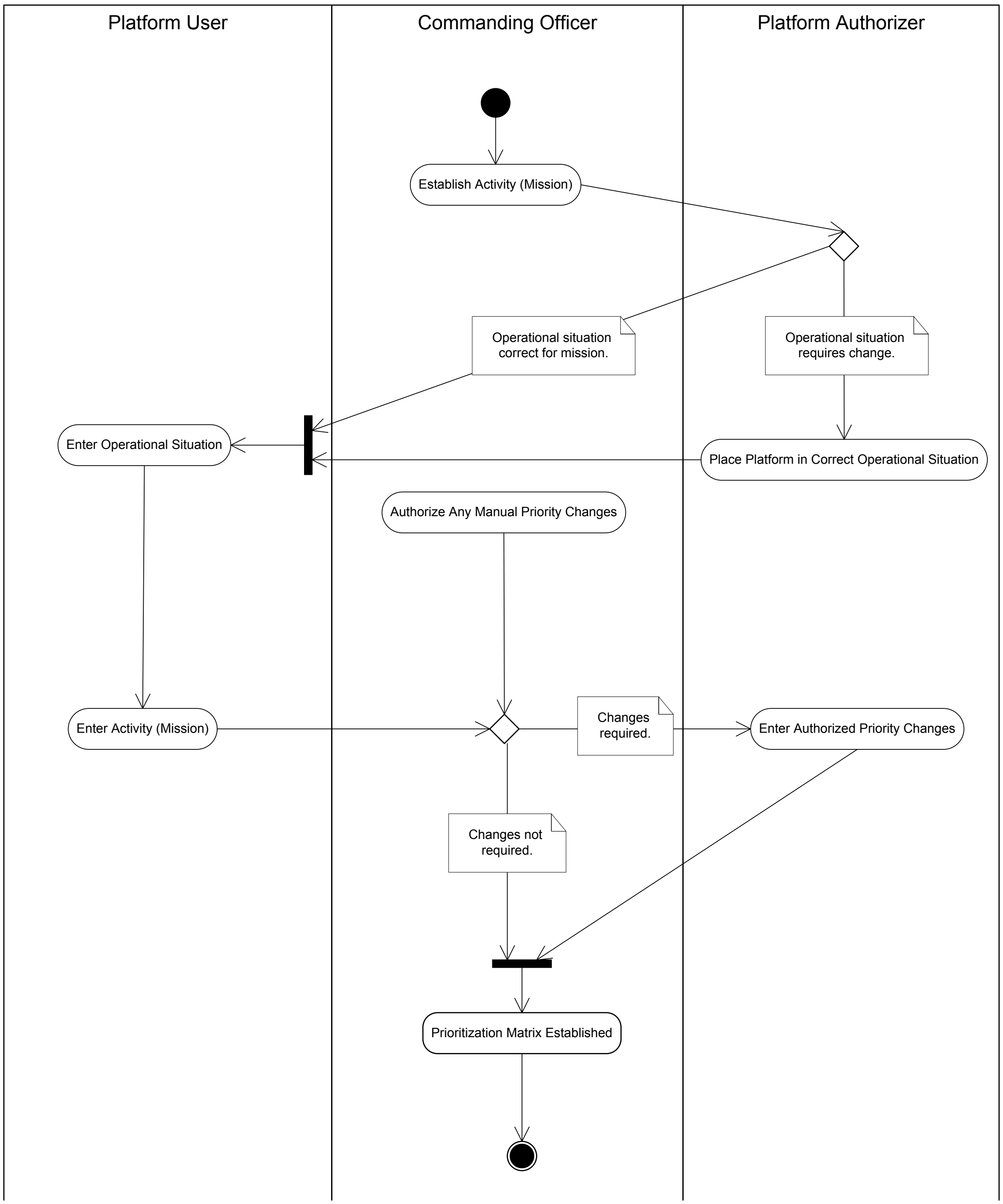


Figure 12. Swimlane Diagram

Defines the business process, key roles, and key responsibilities associated with the Ship-to-shore Data Communication system.

Moving forward with turning this concept of operations into a physical reality, there must be some way to evaluate potential alternate solutions. Thus, a value system must be generated whose primary purpose is to develop a value hierarchy that can be used to evaluate various alternatives. The value system for this project is shown in Figure 13. The value system displays what functions and sub-functions the system must perform to be successful along with goals and requirements against which success can be measured. By evaluating each potential alternative against these measures, the best overall system for meeting the effective need can be determined. A more detailed description of the value system will now be presented.

D. VALUE SYSTEM

The value system consists of three main functions: classify data packets, prioritize data packets, and manage network congestion. It is also comprised of six key behaviors: availability, reliability, usability, maintainability, interoperability, and efficiency. In order to classify data packets, two sub-functions must be performed. First, each data packet type must be successfully identified. This could be accomplished by determining the following information about each packet: port number, application type, source address, source-destination pair, or some other criteria. Second, based on the identifying information determined for each packet, that packet is marked based on its type. This marking will then be used by the prioritization function.

The function performing data packet prioritization consists of two sub-functions: routing to a queue based on the marking and assigning a priority to each queue. Based on the marking applied to each data packet based on its type, data packets are assigned to a particular queue such that each queue contains data packets of similar types. Each queue is then assigned some prioritization level such that higher priority data packets reside in the higher priority queues and lower priority data packets reside in the lower priority queues. Thus, priority level of data packet types could be changed as follows. If a certain data packet type is desired to have a higher priority level, then that can be accomplished by either changing its marking such that it goes to a higher priority queue or changing the priority assignment of the queue to which it is normally sent based on its marking.

The final function the system must perform involves the management of network congestion. In order to do this, the presence of network congestion must first be identified. This identification could be made using such techniques as monitoring queue sizes, measuring output line usage of key network devices, monitoring round-trip delay times, using a source probing scheme to determine network state, or setting a timeout for package acknowledgement. Then, when congestion does exist, it must be alleviated. This could be accomplished via source throttling, source quench, or packet dropping for example.

In addition to system functions, several system behaviors exist upon which alternatives will be evaluated. Availability is calculated as the ratio of the amount of time the system is actually operational to the amount of time it is expected to be operational. Reliability is measured by the average or mean time between system failures requiring corrective maintenance. Usability is defined as the ease with which potential operators can manipulate the system with a reasonable level of training. This behavior will be evaluated based on user satisfaction surveys that will allow an operator approval rating to be calculated. Maintainability is measured by the average amount of time the system is required to be down for a maintenance event. Interoperability is determined by measuring the amount of commonality in terms of language and protocol that the system has relative to existing systems with which it must interoperate. Efficiency represents the percentage of packets required to be dropped as a result of congestion management processes. All goals for these behaviors are given in the Value System diagram of Figure 13.

Thus, alternatives could be evaluated based on both required functions and desired behaviors. This would mean choosing the system that comes closest to meeting all the behavioral goals plus has the highest probability of success in doing the following: identifying data packet types, assigning markings based on those types, routing to proper queue based on marking, assigning correct priority to each queue, identifying network congestion when it occurs, and alleviating detected congestion when required.

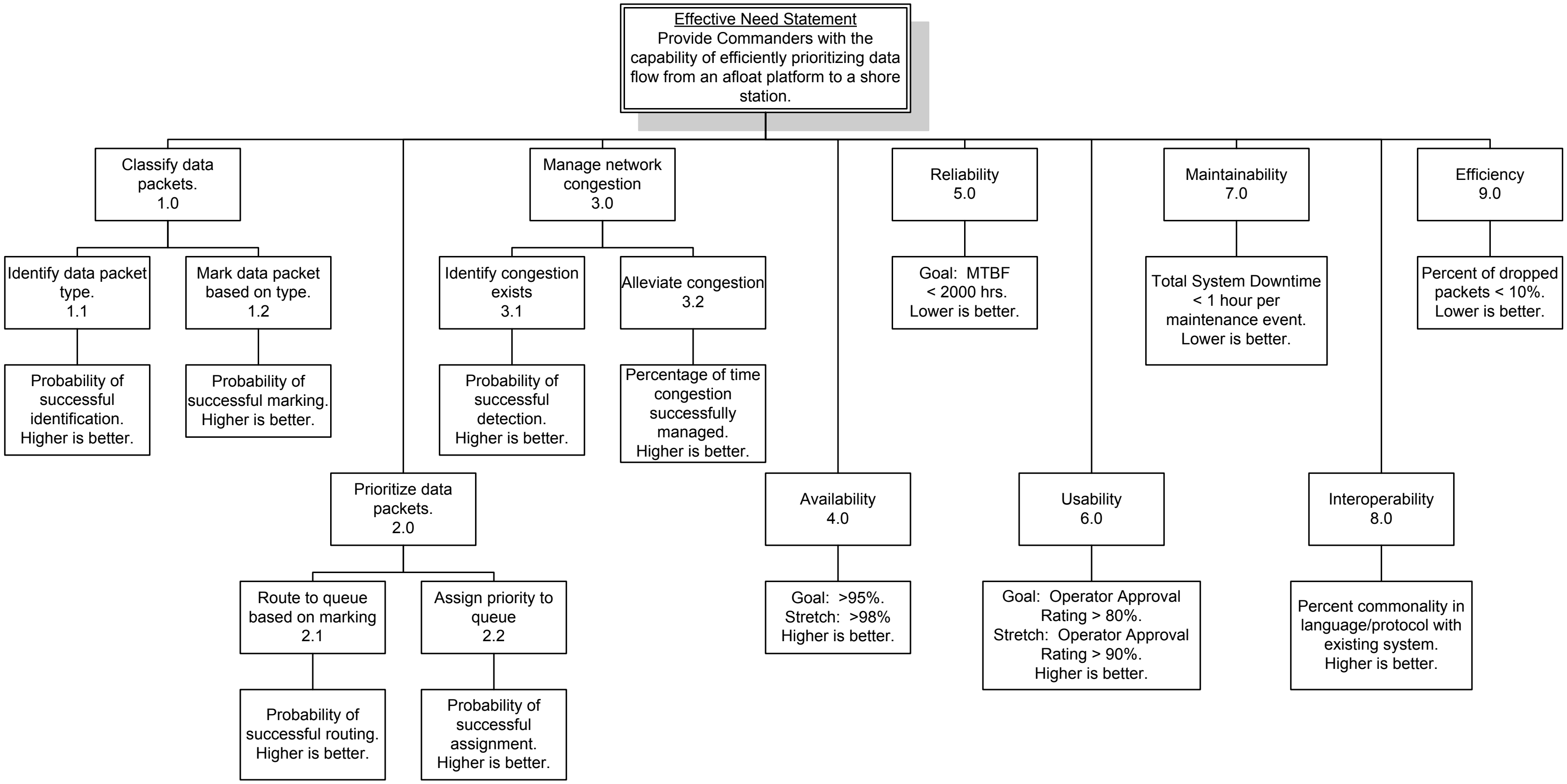


Figure 13. Value System

Lays out the key functions of the Ship-to-shore Data Communication system along with their associated sub-functions and pertinent metrics.

E. OPERATIONAL REQUIREMENTS

Initially, this system will be designed for roll-out to Guided-Missile Destroys (DDGs) and Guided Missile Cruisers (CGs). It is expected that a prototype will be installed on one ship of each class within 18-24 months. Upon successful demonstration of the prototypes, this system will then be installed on two ships of each type per year until fully deployed on all DDG and CG platforms. Consideration of system modification for roll-out to aircraft carriers and amphibious ships (both large and small decks) will be made at later dates. Furthermore, extension of this system to include classified shipboard networks will also be evaluated at a later date. It is anticipated that, once installed, each system will last throughout the remaining life of each ship.

This system will operate 24 hours per day, 7 days per week. It will run as long as the unclassified shipboard networks and their associated applications are running. The only time this system will not be operating is when one or more unclassified networks are down for routine preventive or corrective maintenance. Availability of the system should be greater than 95% with a stretch goal of greater than 98%. MTBF should be 2000 hours. No more than 10% of packets should be dropped on average. The usability of the system should be such that normal shipboard operators can adjust prioritization schemes per the CO‟s direction with nominal "on the job" training. Maintenance on the system will be conducted similarly to existing shipboard network components and systems. Ship‟s force will handle all routine preventive and corrective maintenance. More challenging maintenance items will be shipped off to intermediate maintenance facilities for repair. Major repair requirements will be handled at depot level facilities while the ship is in port.

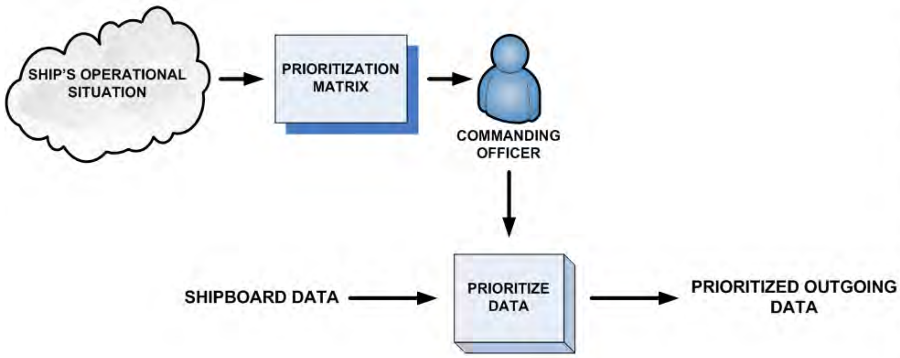
The environment in which this system is expected to operate will be the expected environment to be encountered by Navy ships underway and in port while conducting normal operations.

F. PRIORITIZATION MATRIX

The system must be able to provide the CO the capability to prioritize outgoing shipboard application data based on the ship"s operational situation. As mentioned previously, the ship could be in one of several operational situations such underway in theater, underway in transit, homeport, U.S. port (other than homeport), foreign port, and dry docked. A ship"s operational situation could involve one or more activities such as AD, strike, and ASW. See Table 5 above for a complete list of activities. This research will only consider the underway in theater operational situation as that contains all the activities of interest to this paper. For each activity, there exists shipboard business process data associated with it. These relationships are shown above in Table 6.

1. Operational Situation and Activity Matrix

The matrix in Table 6 serves as a basis in establishing an outgoing shipboard application data prioritization matrix which the CO will input as control for the system. With this matrix, the CO could identify and select which data are applicable to a particular activity within an operational situation. In addition, the CO could assign ranking as to which data get the highest and lowest priority when leaving the ship. This concept is shown in Figure 14 here; the Humanitarian Operations activity is used as an example.



SAMPLE PRIORITIZATION MATRIX

UNDERWAY IN THEATER	Humanitarian Operations
Video	1
Voice	1
Chat	1
Critical E-Mail	1
Medical	2
Engineering	3
3M	3
Administrative	3
Operations	3
Message Traffic	2
Training	3
Non-Critical E-Mail	4
Web Browsing	4

Figure 14. Operational Situation Mapped to Activity Matrix

A storyboard to establish an outgoing shipboard application data prioritization matrix which the CO will input as control for the system.

2. Shipboard Data Prioritization Matrix

In the example above, the Humanitarian Operations mission portion of the prioritization matrix template is considered in isolation. Priorities are assigned to each business process consistent with the CO"s perceived needs based on mission. Here, video, voice, chat, and critical e-mail receive highest priority while non-critical e-mail and web browsing receive lowest priority as is consistent with the CONOPS assumptions. Of the seven remaining business processes, medical and message traffic are assumed to be of greater importance for this mission. Thus, they receive higher priority than the other five business processes. This project"s recommendation is to employ the above discussion as part of the system software. A potential software story board is shown in Figure 15.

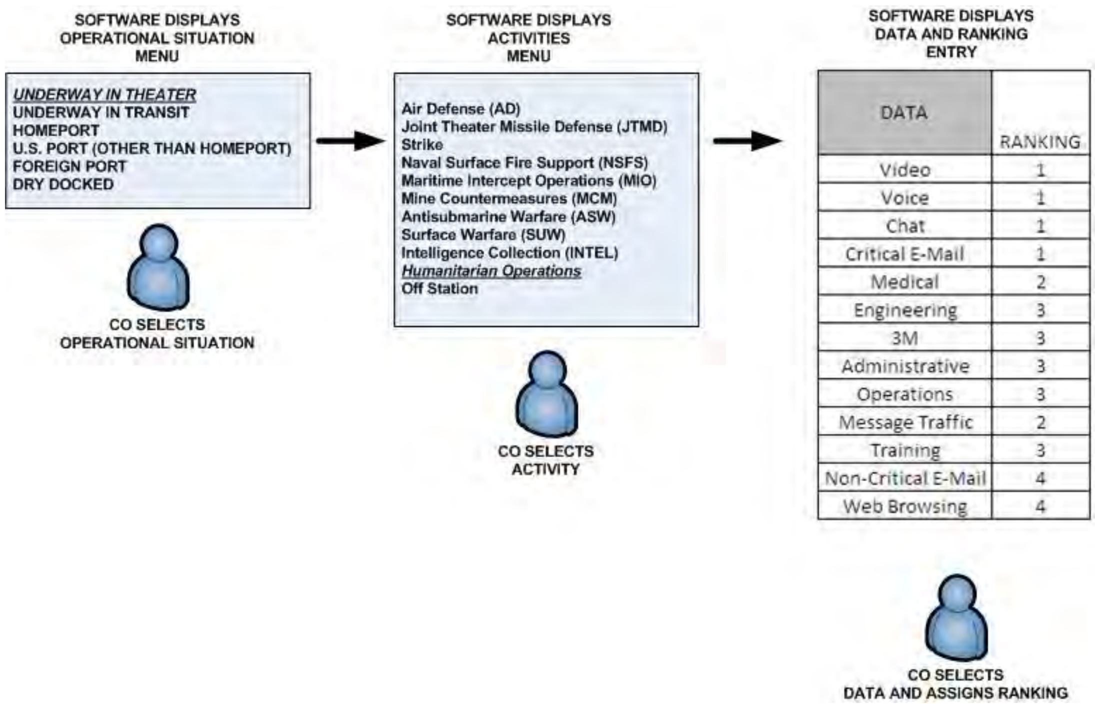


Figure 15. Prioritization Matrix Software Story Board

A storyboard to establish an outgoing shipboard application data prioritization matrix which the CO will input as control for the system.

Internally, the software would map the outgoing shipboard application data prioritization matrix to a list of IPs and ports that identify the data within the network. For example, Medical Info would have a unique source IP address (host) and port number (application) associated with it which will allow the system software to identify it and distinguish it from the other shipboard application data when employing the prioritization algorithm.

G. HIGH LEVEL REQUIREMENTS SUMMARY

The stakeholders and need analysis resulted in a list of capabilities for this effort. These capabilities were then transformed into a set of high level requirements.

The required capabilities for this effort are divided into two areas: user interface and prioritization mechanism. The user interface allows the user (i.e., CO) to enter prioritization information into the system based on the ship's operational situation. The prioritization mechanism translates the user entered prioritization information into algorithms (or policies) that carry out the prioritization tasking. User interface and prioritization mechanism requirements are contained below in Table 7.

Table 7. User Interface and Prioritization Mechanism Requirements

REQUIREMENTS	**STAKEHOLDERS**	**DERIVED**
User Interface Requirements		
The system shall provide a template for users to prioritize data.	**X**	
The system shall provide a user interface to define prioritization information.		**X**
The user interface shall be able to list the different operational situations for its host ship.		**X**
The user interface shall be able to list the different activities (missions) within a particular operational situation.		**X**
The user interface shall be able to list the different data that are applicable to an activity within a particular operational situation.		**X**
The user shall be able to select the applicable data to be prioritized for a particular activity within a particular operational situation.		**X**
The user shall be able to define prioritization by ranking the selected data for a particular activity within a particular operational situation.		**X**
The user interface shall base prioritization information using the user defined ranking of the selected data.		**X**
The user interface shall transmit the prioritization information to the prioritization mechanism.		**X**
The user interface shall allow the user to change prioritization information on-demand (at any time).		**X**
The user interface shall be able to accommodate different sets of operational situations/activities/data.		**X**
Prioritization Mechanism Requirements		
The system shall translate user (war fighter) operational situations into policy.	**X**	
The system shall provide a prioritization mechanism to carry out the prioritization tasking.		**X**
The prioritization mechanism shall receive and translate prioritization information from the user interface.		**X**
The prioritization mechanism shall employ data marking and queuing methodology.		**X**
Data shall be marked based on the type of application it came from.		**X**
Data shall be marked based on its priority.		**X**
The prioritization mechanism shall send high priority data off the ship first.		**X**
The prioritization mechanism shall loop lower priority data back to the main queue.		**X**
The system shall implement different queuing methods to avoid congestion.		**X**
The prioritization mechanism shall apply QoS policies in order to manage the prioritization.		**X**
The prioritization mechanism shall establish a set of QoS policies that can be put in place based on the prioritization information from the user interface.		**X**
The prioritization mechanism shall employ dynamic (non-static) QoS policies that adjust with changes in the traffic profile.		**X**
The prioritization mechanism shall be able change prioritization on-demand in response to changes in user input via prioritization information from the user interface.		**X**

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III. ARCHITECTURE AND SIMULATION

By following the Systems Engineering “Vee” model, this lead to the next steps of identifying architecture views and modeling and simulation that would provide engineering analysis capturing and simulating the problem. In identifying which architectures to utilize, careful consideration was taken to make sure that the views would represent the problem statement and identify the flow throughout the system process. In the next sections, the views that were thought to be most vital in telling the story are discussed. Then the modeling data and analysis provides simulated verification and validation to the alternatives that are formulated.

A. ARCHITECTURE

The architecture products are developed from the viewpoint of the ship. Additional stakeholders for this architecture are depicted in a generic context since the focus of the capstone deals with the handling of information on the ship. Hence as will be shown throughout the discussions in this section the use of generic entities versus specific operational entities is the default.

The objective was to describe the „As-Is‟ architecture as the basis and context to describe the „To-Be‟ architecture which represents the focus of the capstone. All architecture products developed are located in Appendix A.

1. High-Level Operational Concept Graphic (OV-1)

The high-level operational concept graphic describes a capability and highlights main operational nodes and interesting or unique aspects of operations. It provides a description of the interactions between the subject architecture, naval environment, and between the architecture and external systems.

The OV-1 describes the operational focus of the ship on supporting ship-to-shore data communications. The view was designed to represent seven data areas within the ship that would be prioritized before being transmitted off the ship. The seven applications are medical info, operations, 3M data, administrative data, engineering data, message traffic, and training data. The view illustrates the operational environment of a ship, mentioned capabilities, and the performers exchanging information in support of the missions. The arrows and lightning bolts depict the ships communications and connectivity with U.S. NOCs and shore facilities.

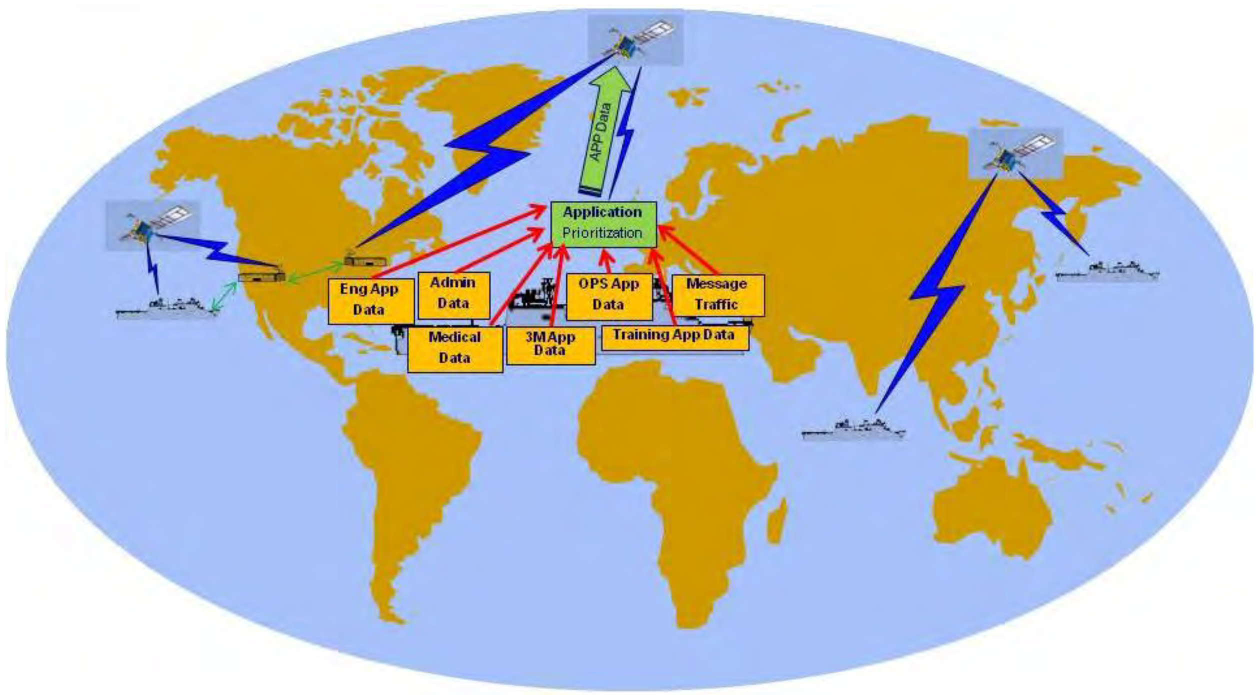

Figure 16. High-Level Operational Concept Graphic (OV-1)

The OV-1 high-level operational concept graphic describes the capability and highlights main operational nodes and interesting or unique aspects of operations.

2. Operational Node Connectivity (OV-2)

The OV-2 graphical depiction shown below in Figure 17 provides an overview of the data which flows from a typical USN afloat vessel underway and in port. The OV-2 highlights the typical generic data nodes by subject. It's understood that these generic nodes would actually breakout into multiple nodes however, to reduce the time required for research and the overall complexity of the OV-2, the decision was made to use generic subject nodes.

The OV-2 is focused on data sources that have the ability to either send or receive or both send and receive the specific type of data displayed in the node name. This OV-2 demonstrates the sharing of high level Information between the shore data source and the afloat ship. Specifically the information depicted is (medical info, operations, 3M data, administrative data, engineering data, message traffic, and training data) as these are the primary areas for conducting routine business when a ship is underway or in port.

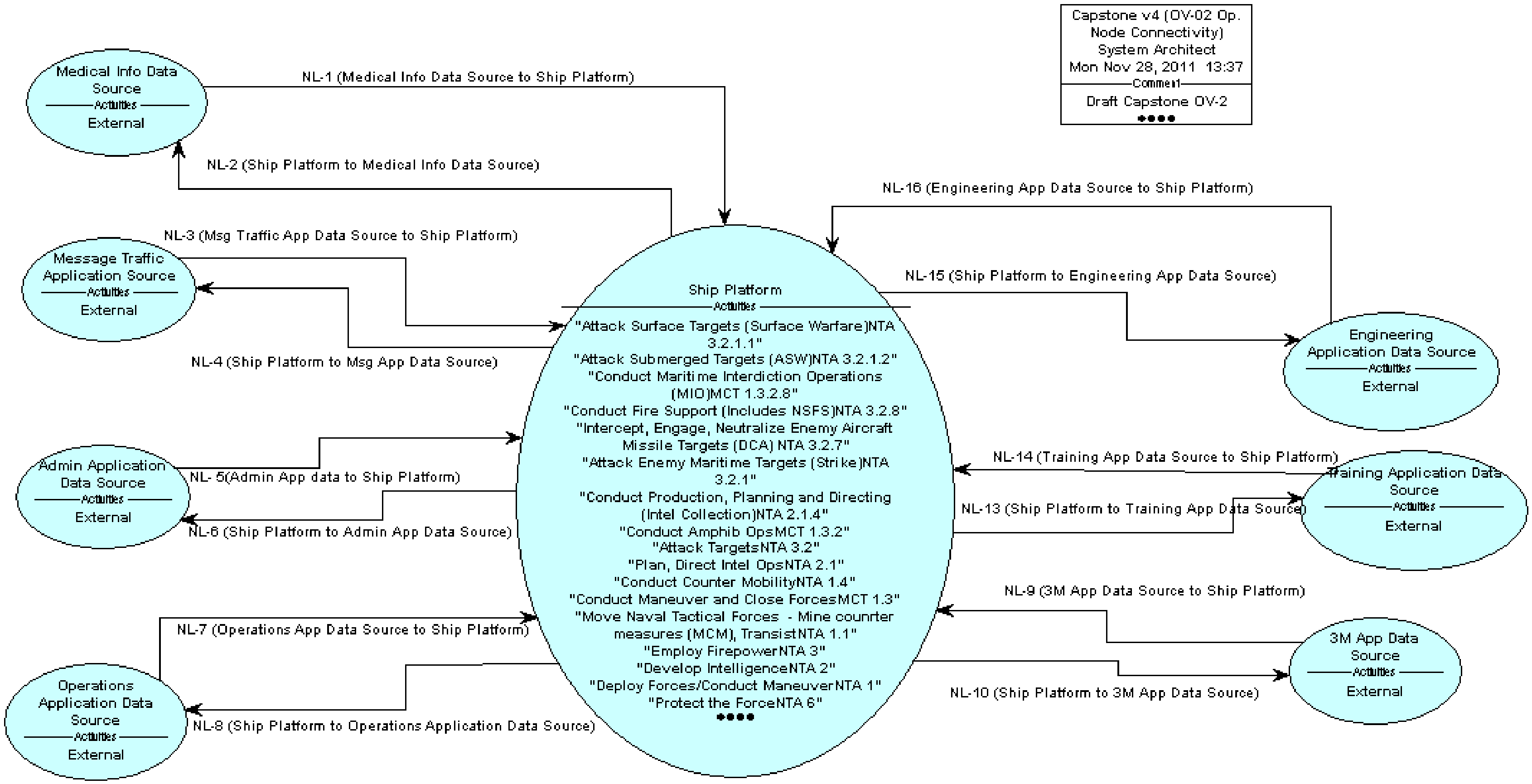

Figure 17. Operational Node Connectivity (OV-2)

The OV-2 depicts the nodes and need-lines for the capstone project.

B. MODELING AND SIMULATION

Communication of data off a USN ship underway is questionable at best. External environmental factors affect the ability of a ship to maintain a constant data signal. These environmental factors include sea state, adverse weather, and availability or the satellite for communication. Structural factors of a ship also affect the ability to maintain a constant connection such as when the ship‟s course puts the mast or superstructure between the antenna and satellite. The unreliable means for transmitting data often results in a backlog of data needed to get off the ship. Modeling and simulation is used to test and provide analysis to different aspects of this problem.

Two models were utilized to show different perspectives of the problem. The first model was developed using ExtendSim7™, to determine if applying data marking and priorities would result in a higher or lower throughput of prioritized data. The second approach used the Joint Communication Simulation System (JCSS), a network modeling tool. The JCSS model was developed, to extended the concept of priority queuing and demonstrate the advantages of some of today‟s advanced QoS techniques. The JCSS baseline scenario showed a QoS enabled network. Within the QoS network, it can be shown that by manipulating differentiated code services point values according to the operational context, results in the increase of some traffic patterns. Traffic throughput can be improved for the contextually high priority applications.

1. ExtendSim7™ Modeling Approach

The first model was developed using ExtendSim7™ to determine if marking and applying a prioritization to packets developed by different applications and put through a prioritized queue resulted in a higher transmission rate for applications with a higher priority. This model was created using discrete modeling to apply properties to the packets as they were developed. As packets were developed, to simulate the development of different types of applications, the packets were filtered through different application paths using probabilities to simulate application data rates. The packets were then given a priority and size as properties. As the packets make their way through the prioritized queue, transmission times are simulated by going through an activity that holds the packet based on the packet size. After packets make their way through the transmission activity, the packets are then sorted to the different application and packet transmission time is recorded. The process described here is representative of how packets are developed by different applications within the framework of a ship‟s network infrastructure and pass through ADNS for transmission off the ship.

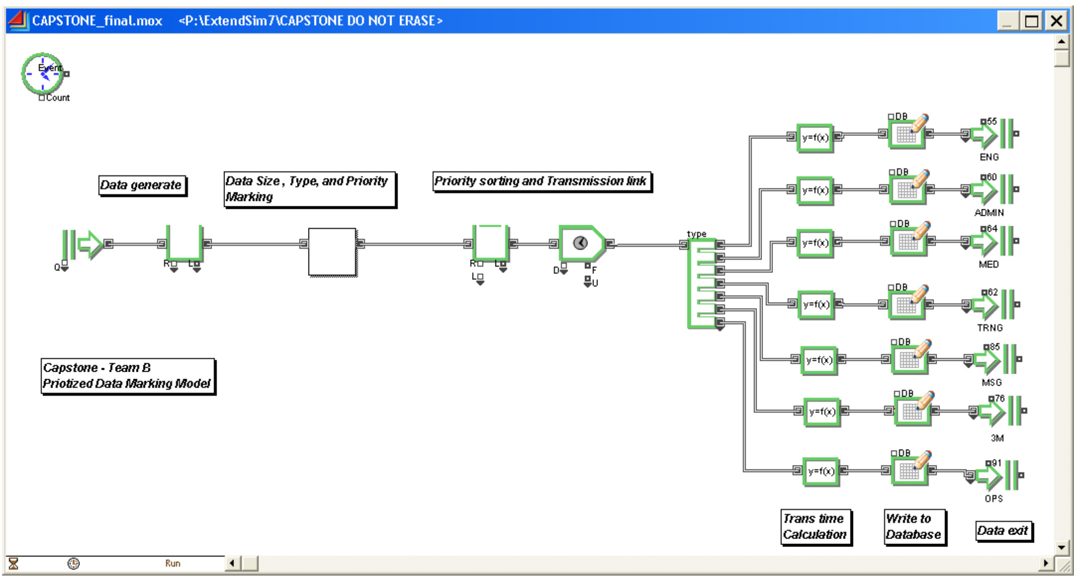

Figure 18. Priority Data Marking Model

The model that was developed using ExtendSim7TM to apply prioritization of packets and to compare transmission rates.

2. ExtendSim7TM Simulation Parameter

The following variables exist in the ExtendSim7TM model; packet generation rate, packet size, packet type, and the priority set for each packet type. The size, type, and rate were used as constants in the model to compute transmission times as affected by changes in priorities.

3. ExtendSim7TM Simulation Results

Appendix B contains the data collected from the ExtendSim7TM modeling and simulation effort. The ExtendSim7TM modeling and simulation data was analyzed to prove the statistical validity of the following three main inferences: 1) the average transmission time for each data category is approximately equal in a FIFO methodology,

2) the average transmission time for a data category will decrease based on the priority level assigned to a data category and 3) the average transmission time for a data category having the same priority level will be approximately equal.

The data of Appendix B was gathered from two distinct models; a base model and a priority model. The base model captures the average transmission time for every packet when each data category is assigned equal priority (FIFO). The priority model captures average transmission time for each data category as it is assigned a distinct priority level.

As the population sample sizes for both models are all equal, the sample sizes of both models are balanced [Hayter, 2007]. The base model has seven factor levels corresponding to the seven populations under consideration. The priority model has three distinct factor levels corresponding to the three populations under consideration. In the base model equal priority levels are assigned to each of the seven data categories. Factor levels in the priority model are assigned a priority level of one, two, or three. An Analysis of Variance (ANOVA) is the statistical methodology used to analyze the resulting data. The null hypothesis for each ANOVA states that there is no difference between the population means of each data category.

Figure 19 is a boxplot of the average transmission times of each data category from the base model. The data of Figure 19 suggest that the average transmission time for each data category is approximately equal when a FIFO methodology is applied to the base model. The statistical significance of this hypothesis is shown to be extremely plausible (see Appendix B) as the p-value of the ANOVA is much greater than 10% [Hayter, 2007]. The Tukey method is used to conduct a pairwise comparison between the factor levels of the base model, and it is determined that there is no significant difference between factor levels. Thus, it is safe to conclude that there is no difference between the average transmission times of each data category when it is subjected to a FIFO methodology.

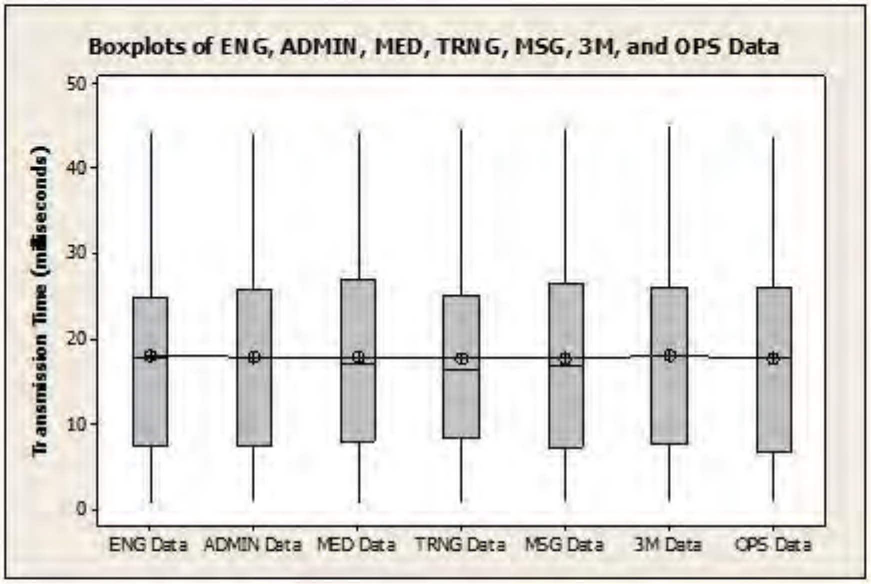

Figure 19. Boxplot of Base model average transmission times for each data category

Average transmission times for each data category.

Figure 20 and Figure 21 illustrate the transmission times for engineering and training data when they are assigned priority level one, administrate and message traffic data when they are assigned priority level two, and medical and 3M data when they are assigned priority level three. The data suggests that the average transmission time and variance increases as the priority level increases. The ANOVAs for both Figure 20 and Figure 21 prove this hypothesis to be highly plausible as the p-values are much less than 1% [Hayter, 2007]. The Tukey method is used to conduct a pairwise comparison between the factor levels of priority one, two, and three. The Tukey method affirms that data categories assigned priority level three are significantly different than the data categories assigned priority levels two and one. Data categories assigned priority levels two and one, are not significantly different. Thus, it is reasonable to conclude that the average transmission time for a given data category will decrease based on the priority level assigned to it as long as other packets exists with a lower priority. This is a direct relationship and relies on taking bandwidth from lower prioritization data to provide to higher prioritized data.

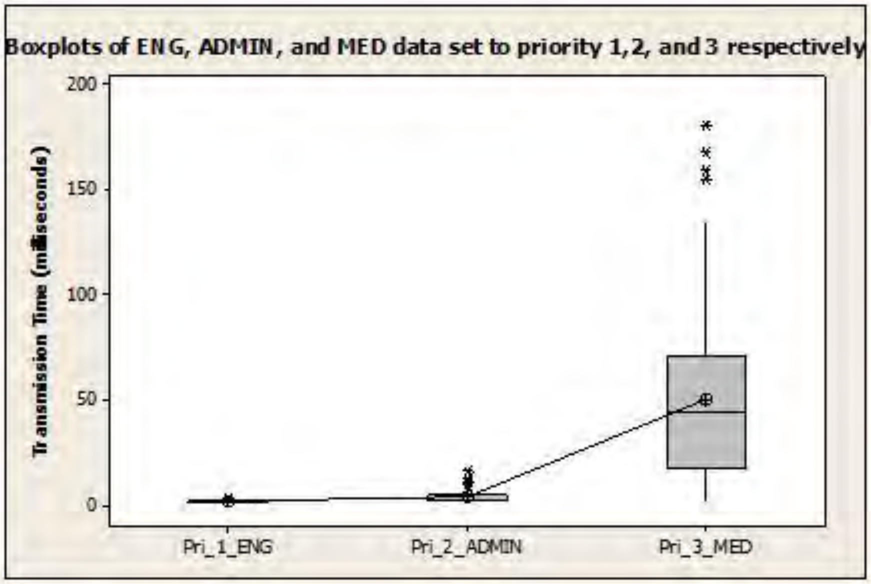

Figure 20. Boxplot of transmission time for prioritized data

Transmission time for Engineering (ENG), Administrate (ADMIN), and Medical (MED) data when assigned priorities 1, 2, and 3 respectively

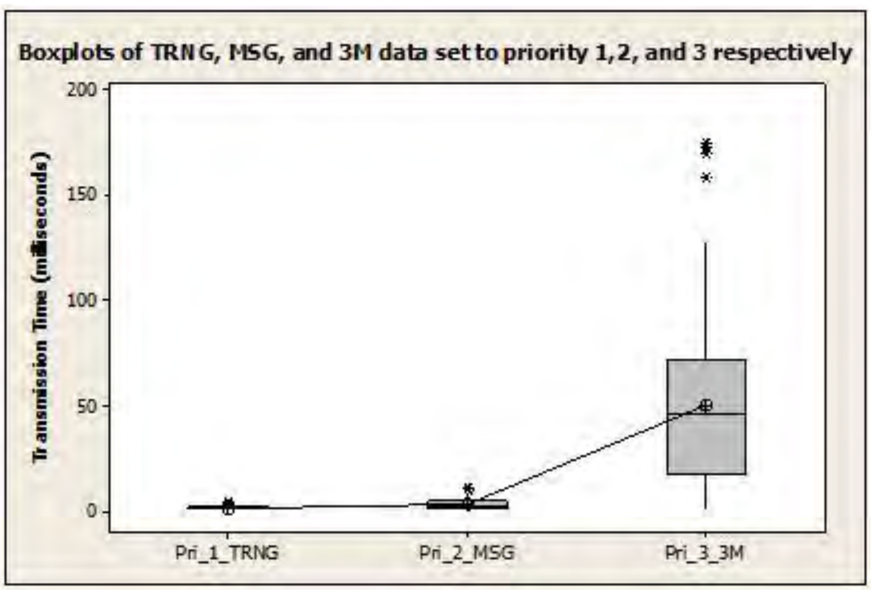

Figure 21. Boxplot of transmission time for prioritized data

Transmission time for Training (TRNG), Messaging Traffic (MSG), and 3M data when assigned priorities one, two, and three respectively

Figure 22 depicts the boxplots of each data category as it is assigned priority level one. The data suggests that the average transmission time for each data category is approximately equal when each data category is assigned the same priority level. The ANOVA proves this hypothesis to be highly plausible as the p-value is much greater than 10% [Hayter, 2007]. The Tukey method is also used to conduct a pairwise comparison between the transmission times for each factor level. The Tukey method found that there was no significant difference between engineering, training, or operations data when assigned the priority level of one. Thus it is safe to conclude that the average transmission time for data categories having identical priority levels is approximately equal.

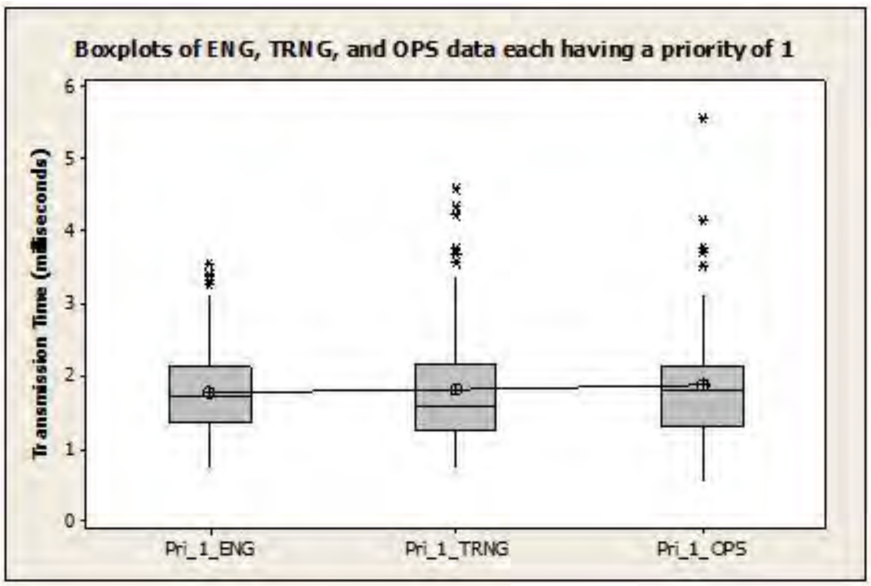

Figure 22. Boxplot of highest priority transmission times

Transmission times when each data category is assigned priority level one

4. JCSS Model

The JCSS is a network modeling and simulation tool developed and maintained by the Defense Information Systems Agency (DISA). JCSS is based on the Optimized Network Engineering Tool (OPNET) commercial software package. JCSS version 10.1 was used for this effort.

JCSS was developed by DISA to help military planners consider their in-theater-communication needs. It allows the communications specialist to visualize and describe the networks used for various military units. The tool is specifically designed to help identify potential bottlenecks for the communications infrastructure. JCSS helps planners understand the flow of time critical messages through the system and whether the planned infrastructure is sufficient to satisfy the demands of the mission.

JCSS allows the user to construct a virtual representation of the network infrastructure imposed over a map and then simulate the message flow through this structure. The basic framework for analysis is the use of scenarios. Typically, a user creates a baseline scenario. Then this baseline is modified in various other scenarios that are compared to the baseline and each other. The tool provides the user with maps, upon which Operational Facilities (OPFACS) are placed along with their associated communications equipment. JCSS provides a palette of hundreds of generic and commercial communication devices that are used to represent the network infrastructure. Once these devices are placed and grouped into their OPFACS, they are configured much like their real world counterparts to create a virtual network. Once the network is in place, the user can then specify Information Exchange Requirements (IERs) between OPFACS and identify detailed Measures of Performance (MOPs) to determine the efficacy of the network.

5. JCSS Model Objective

The objective of the simulation was to compare the performance of ship-to-shore communications using a "best effort" strategy against a differentiated services QoS strategy. A "best effort" strategy is the default quality of service strategy afforded by networks. In a "best effort" approach, all IP packets are treated equally. This baseline is representative of the current state of the ADNS network. The fundamental problem with treating all packets equally is that all packets are not truly equal. Certain packets, such as routing information, are more important because they are essential to the overall health of the network. Depending upon the operational context, the network user will value certain information more than other information. Consider, as a home network user, a scenario in which a person is watching a movie streamed over the internet or playing an online game. In this scenario, the person would typically consider the packets containing the movie stream or the game moves more important than email, or a large file download that is happening in the background. With a best service approach, all the traffic is treated equally and therefore, the home user experiences lots of delays and interruptions in their movie watching or gaming experience.

Networks are typically configured to provide preferential treatment to certain classes of network traffic. While it is standard practice to configure streaming traffic to take precedence over non-streaming traffic for obvious reasons, many networks do not extend the use of QoS techniques beyond this level. While it is helpful to use a home network as an example to help readers understand the basic concepts behind QoS policies, one must take care not to extend the example to far. One big and obvious difference between a home network and a USN ship is that a home network typically only has one type of priority message traffic occurring at a time. That is to say that a typical usage scenario such as watching a movie or playing an online game most often occurs while not much else is happening on the network. If the teenage son wishes to game online while his parents stream a movie over a best effort network, the parents are able to simply shutdown the game traffic by telling the son that he will have to wait until they are done watching the movie. Aboard a naval vessel, there are typically multiple priority communications happening all at once. A multiple priority scenario cannot be handled in a binary fashion that can be considered acceptable in a home network. That is to say that in a multiple priority scenario, it is undesirable to shutdown all other traffic to allow one particular flow of traffic exclusive access to the network.

Instead of switching various traffic channels on and off, differentiated service codes can be used to achieve satisfactory performance across the broad spectrum of messages that must be communicated. In order to provide satisfactory performance, network performance must first be understood. Network performance can be characterized in at least four different ways: speed, bandwidth, throughput, and latency.

The term speed, when used in networking, tends to be related to rated speed of a network device or connection. This term is generally not useful as a MOP since it represents a theoretical limit that is unachievable in the real world. While it is true that a 100BASE-T line can carry data faster than a 10BASE-T line, this fact is used more for the planning of networks than as a measure of performance.

While the term bandwidth refers to the data-carrying capacity of a network link, it too, is largely a theoretical limit. As a result, it is more useful for us to consider the throughput and latency as measures of performance. Throughput measures the actual amount of data that is actually being sent across a network. Speed ratings and bandwidth of network components ultimately limit throughput. Network phenomena such as congestion (high percentage of packet collisions) degrade throughput. However, in an optimally configured network, throughput cannot be increased beyond the theoretical or practical limits of the physical network. Therefore, in a saturated network condition, *ceteris paribus*, throughput is considered bound for the purpose of this study.

The primary MOP is latency which deals with the timing of data transfers through a network. Latency, like many other performance measures is multifaceted. A typical usage of the term latency deals with the elapsed time between a request and a response. Streaming media applications are particularly sensitive to this type of latency. An on-line game cannot tolerate this type of latency since the user would experience a noticeable lag between the times the controller button is pressed to the time the resulting action appears in the game. Similarly, fire control systems are very intolerant of this type of high latency. However, other systems are generally more elastic in their ability to tolerate this type of latency. As an example, email systems are specifically designed to support delayed delivery. A user composes an email message. The message is then queued for delivery until a network connection is available. The acceptable length of delay from the time the user "sends" the email to the time it is ultimately received by its intended recipient is very elastic. Even when the message is delivered immediately upon being sent, the recipient may not check his email for several hours or days after the message is received in his inbox. Depending on the nature of the email message, this delayed delivery is acceptable up to some amount of time that is wholly dependent upon the content of the message and the context in which it was sent. Certainly, some email messages are more time sensitive than others. Even still, this sensitivity is generally measured in hours or days, instead of milliseconds.

In scenarios that involve lossy or intermittent connections, a backlog of messages can build up during periods of disconnectedness. If the connection is in and out such that prolonged periods of connectivity are a rare occurrence, the network never achieves a stead state in which there is little or no backlog. It is in this scenario in which the prioritization of messages becomes critical. Whenever connectivity is reestablished it is important that the most critical messages be delivered first since it is unknown how long the connection will last. Applying a FIFO approach in this type of network equates to a best effort approach. This means that letters to friends could be delivered before mission related data. This research looked at ways to leverage QoS policies to ensure that the most contextually important data receives priority treatment and is always delivered first. This approach cannot eliminate delays due to loss of connectivity. However, it will minimize the resultant delay for the most important data in the context of the current mission.

Thus, the primary MOP for this study is message delay. The purpose of the JCSS model is to show that differentiated service codes can be used to minimize message delay relative to other message traffic. QoS technologies typically manipulate messages at the packet level. This fact presents a limitation to the degree to which traffic can be prioritized. If email is considered as an example, all email looks the same to the network. All email traffic emanates from the same port and uses the same protocols. However, an email to a high school friend certainly has a lower priority aboard a ship than a mission related email. To achieve this finer grain of prioritization, there are 63 differentiated service code point values. Obviously, there are not enough code values to provide an arbitrary level of prioritization. However, the use of these codes can provide an incremental improvement. Obviously, better control can be gained at the application layer. Initiatives like NIAPS have attempted to address this by providing a single communication bus for a wide variety of applications. By forcing all applications to communicate through a single bus, prioritization at the application level can be achieved. This prioritization is still accomplished using queuing technology like Multi-Server Multi-Queue (MSMQ) or Java Message Service (JMS). Unlike router queues, these queuing technologies are backed by database stores, allowing an enormous number of messages to be stored in a semantically complete form as opposed to the volatile and potentially network router queues. This application layer approach deals at the transactional or other application-based and semantically meaningful package level as opposed to treating individual IP packets on a case by case basis.

6. JCSS Model Details

The network model used in this project is based upon the overall network configuration of ADNS. ADNS is the WAN interface that connects ships to the tactical network over a satellite link. The model is a very simplified representation of the JCSS network, consisting primarily of basic routers and switches with application servers and simple workstation clients. Advanced technologies like HAIPE are not included in the model even though they exist in the ADNS because they were not considered germane to the study. Similarly, the satellite link is simulated by a 1.5Mbps Point-to-Point Protocol (PPP) link instead of using a real satellite model object. The JCSS model is depicted in Figure 23.

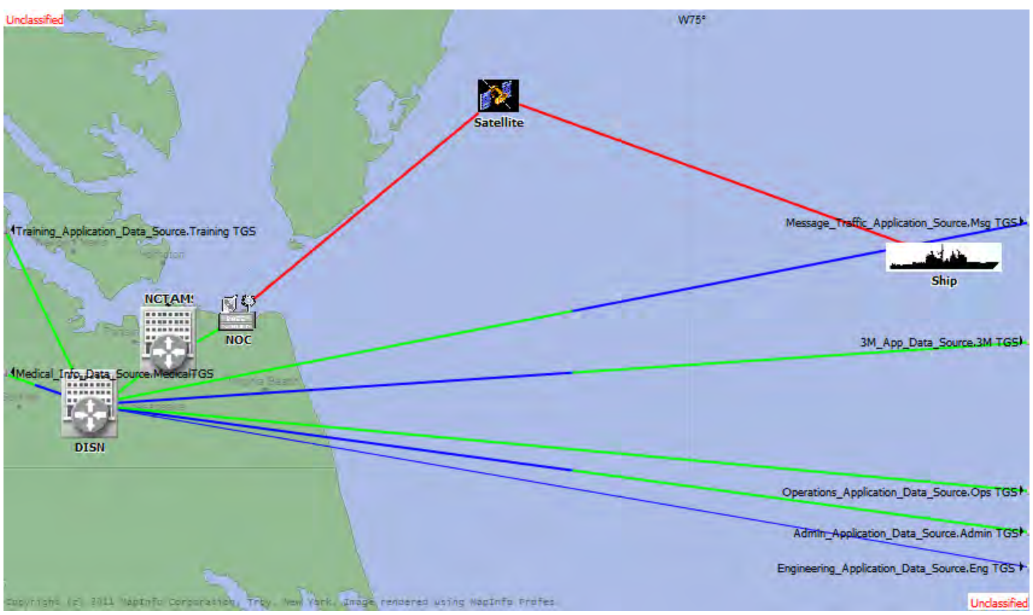

Figure 23. Network Model (Top Level view)

JCSS Model depicting ship-to-shore communications.

Several servers are configured aboard ship and connected through a switch that is then connected to the shipboard ADNS router (Figure 24). This subnet is notional and is not intended to represent any particular real world shipboard network such as ISNS. The servers merely represent message traffic endpoints. All QoS is configured on the outbound satellite interface on the shipboard router. This study focused on ship-to-shore traffic so no QoS is assigned for inbound traffic. Similarly, this study is not concerned with traffic between hosts aboard ship.

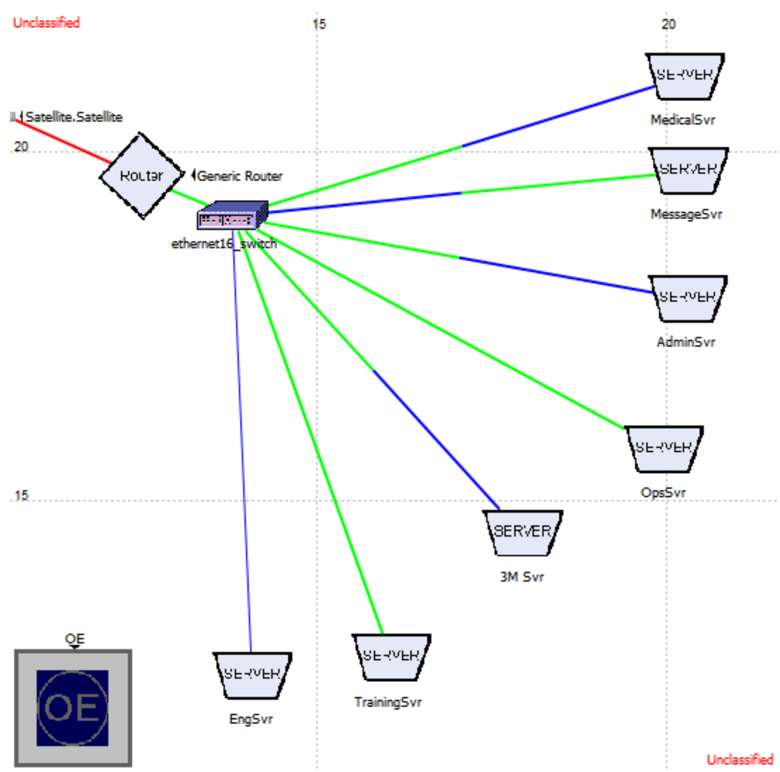

Figure 24. Shipboard Network

JCSS model of servers that are configured aboard a ship and connected through a switch that is then connected to the shipboard ADNS router.

Figure 25 shows a top level view of the IER demands. These demands connect various ashore OPFACS to shipboard servers. Simple workstations serve as traffic generation sites in each of these OPFACS ashore.

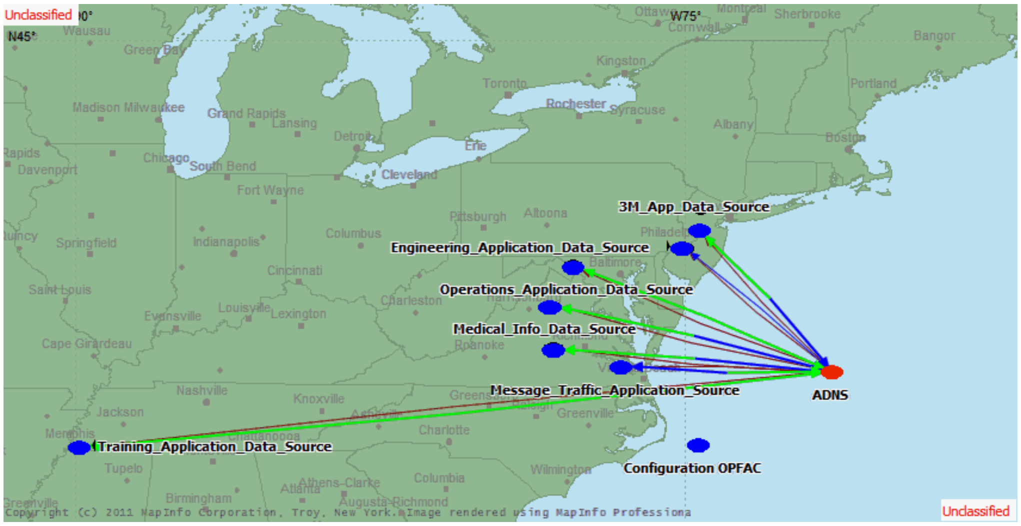

Figure 25. Top Level View of IER Demands

Shows a top level view of the IER demands which connect various ashore OPFACS to shipboard servers

Figure 26 shows a typical ashore OPFAC configuration. The messages that are passed between nodes are generated automatically from the information exchange requirements in the OV-2.

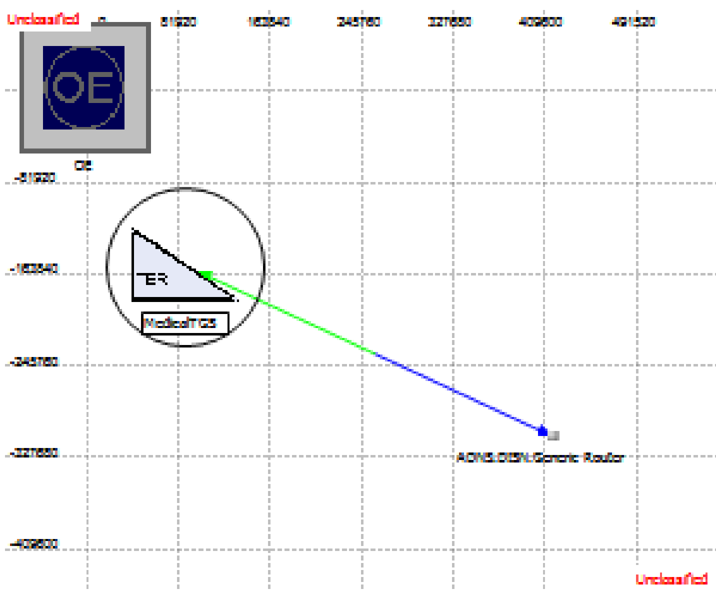

Figure 26. OPFAC configuration

Shows a typical ashore OPFAC configuration.

Figure 27 depicts an OV-2 as configured in the JCSS model. These IERS represent only a small subset of the IERs depicted in the model for the sake of simplicity. The IERS are listed in Table 8. All traffic generated in the model represents one or more instances of IERs.

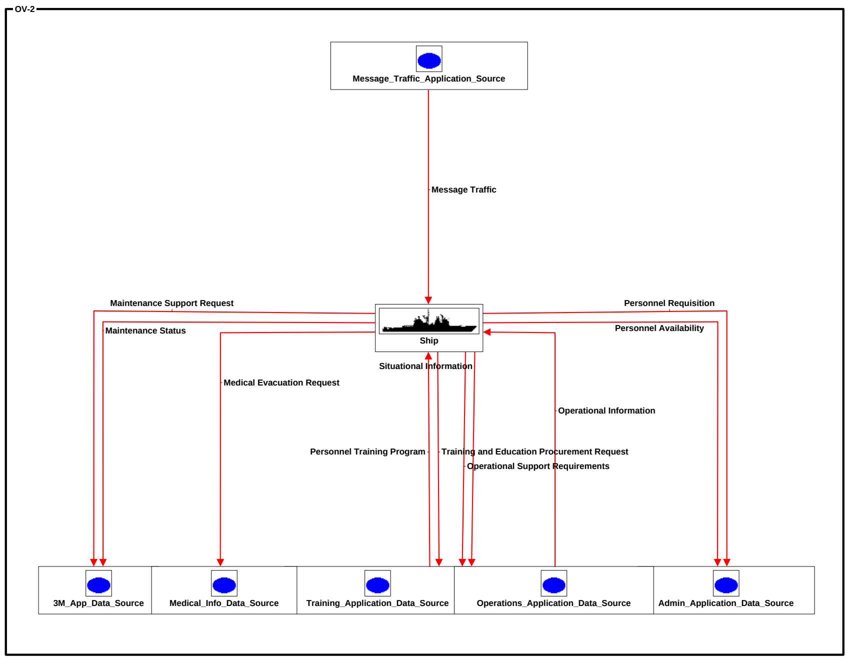

Figure 27. JCSS generated OV-2

Depicts an OV-2 as configured in the JCSS model.

Table 8. JCSS Model Information Exchange Requirements

Consumers	Name(s)	Type	Equipment	Protocol	Classification	Priority
ADNS.Ship.MessageSvr	Message Traffic	DATA	Computer	TCP	Unclassified	ROUTINE
3M_App_Data_Source.OE	3M Svr --> OE	DATA	Computer	TCP	Unclassified	ROUTINE
3M_App_Data_Source.OE	Maintenance Support Request	DATA	Computer	TCP	Unclassified	ROUTINE
ADNS.Ship.OpsSvr	Operational Information	DATA	Computer	TCP	Unclassified	ROUTINE
Operations_Application_Data_Source.OE	Operational Support Requirements	DATA	Computer	TCP	Unclassified	ROUTINE
Operations_Application_Data_Source.OE	Situational Information	DATA	Computer	TCP	Unclassified	ROUTINE
ADNS.Ship.TrainingSvr	Personnel Training Program	DATA	Computer	TCP	Unclassified	ROUTINE
Medical_Info_Data_Source.OE	Medical Evacuation Request	DATA	Computer	TCP	Unclassified	ROUTINE
Admin_Application_Data_Source.OE	Personnel Requisition	DATA	Computer	TCP	Unclassified	ROUTINE
Admin_Application_Data_Source.OE	Personnel Availability	DATA	Computer	TCP	Unclassified	ROUTINE
Training_Application_Data_Source.OE	Training and Education Procurement Request	DATA	Computer	TCP	Unclassified	ROUTINE

Custom configured application objects were used to generate traffic in a baseline scenario and a humanitarian mission scenario. The simulation was configured for seven custom applications (administrative, medical, 3M, engineering, training, operations, and message traffic) in JCSS with various JCSS tasks that represent IERs. JCSS provides the task object to allow simulation of patterns of traffic exhibited by an application. All custom applications were configured identically and were assigned one or more tasks, each of which is configured identically. The basic task includes a 1KB request from an application client and a 100MB response from the respective server. Differences in completion time will be directly related to network delays. During the humanitarian mission scenario, medical data is expected to have higher priority.

7. JCSS Baseline Scenario

The baseline scenario represents a condition in which no IP QoS is configured. This configuration does not provide differentiated quality of service based on any type of service class. Consequently, all packets are treated equally in a best effort configuration. Best effort is JCSS‟s default router configuration for all router model interfaces. However, this scenario uses a FIFO queue. With the FIFO queue profile applied, the router interface queues and process packets in the same order as they would in the default configuration. The FIFO profile is applied because it allows us to limit the number of packets that can be queued. The FIFO profile also facilitates the gathering of network interface statistics. Both of these features facilitate comparisons between this scenario and other scenarios in which IP QoS is configured.

8. JCSS Baseline Results

As expected, the equally configured applications exhibit a near uniform distribution of response times. The application response time represents the time it takes for a series of request and response messages between a client and server participating in a defined series of transactions.

Table 9. Application Response Time in seconds (per 16 MB transactions)

Statistic	Average	Maximum	Minimum
3M (seconds)	4,025.90	4,128.40	3,936.35
Admin (seconds)	4,006.12	4,100.86	3,952.36
Medical (seconds)	4,003.92	4,040.63	3,960.54
Messaging (seconds)	5,962.32	6,008.14	5,916.51
Operations (seconds)	5,941.94	6,048.00	5,792.28
Training (seconds)	4,000.32	4,113.71	3,916.56

9. Humanitarian Mission Scenario

The humanitarian mission scenario is configured identically to the baseline scenario with two exceptions. First, a class CBWFQ QoS policy with WRED for congestion management is used instead of the simple FIFO queues. Secondly, demand signals are substituted for the IERs. The IERs are a simplified form of demand signal. JCSS IERs use the basic type of service field as described in Request for Comments (RFC) 791 instead of the more modern and expanded Diffserv field defined in RFC 2474. The demand signals allow for DSCP marking, a critical feature for this study. The message size and inter-arrival rates are specified the same for both types of demand signals. IERs were used in the baseline scenario which allows the use of Department of Defense Architecture Framework (DoDAF) based architectural design as direct inputs to the model. The QoS policy is configured on the shipboard ADNS router at the outbound satellite interface. The traffic is divided into two different types of traffic that are based on the DiffServ service classes identified in Net Centric Implementation Document

(NCID T300). The traffic flows are asymmetric with a volume in excess of the satellite link capacity flowing from ship-to-shore. The traffic in the reverse direction does not cause any network congestion. The DSCP value assigned to the medical traffic is assigned to a service class in one of the CBWFQ Scenarios. Figure 28 illustrates how a CBWFQ policy works (Figure 28 is taken from JCSS 10.0 Code of Best Practices).

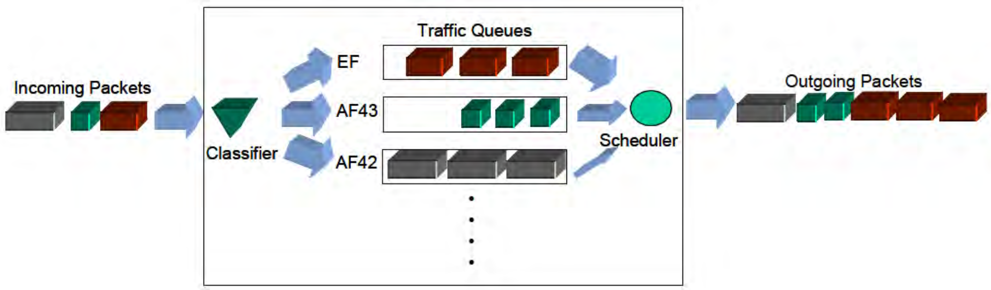

Figure 28. CBWFQ

10. Humanitarian Mission Results

Table 10. Application Response Time in seconds (per 16 MB transactions)

Statistic	Average	Maximum	Minimum
3M (seconds)	2,012.11	2,125.92	1,949.05
Admin (seconds)	4,045.42	4,123.76	3,969.57
Medical (seconds)	1,987.64	2,072.74	1,894.53
Messaging (seconds)	10,012.95	10,063.45	9,962.45
Operations (seconds)	5,998.20	6,063.12	5,915.34
Training (seconds)	4,019.54	4,104.73	3,867.74

C. ANALYSIS OF RESULTS

The results of the simulation conducted within the JCSS tool show the potential for applying QoS data marking to affect a faster throughput of prioritized data over the baseline network configuration. In this simulation, the CO applied a higher QoS marking to be applied to medical data, thus significantly reducing the application response time from 4,003.92 seconds to 1,987.64 seconds.

In steady state operations, this priority is not a big concern. However, ships lose connectivity quite frequently and may only experience short intermittent periods of connectivity. This lack of connectivity can create a large backlog of outbound traffic. The next period of connectivity may not last long enough to clear the backlog. It is in this scenario that data prioritization becomes critical. By using a prioritization matrix to adjust QoS policies, the CO can dramatically increase the probability that the most mission critical data gets delivered in a timely fashion.

The applications response times under the QoS configuration (see Table 10) exhibit preferred treatment of the prioritized traffic. These results demonstrate the effectiveness of a data marking QoS strategy. The medical data traffic was assigned a DSCP value of AF21 while the other application messages were given best effort treatment. The AF21 (010010) DSCP value is low packet drop, assured forwarding traffic classification. The AF21 router queue was assigned 90% of the available bandwidth for the slot, after a 25% reservation for router overhead traffic. The remaining 10% of the slot bandwidth was allocated to the rest of the traffic. At the simulated traffic load, congestion was not prevalent so the effect of WRED policy was not demonstrated. Traffic loads were not increased beyond this level because the increased load would not be representative of the applications being simulated and traffic prioritization vice congestion management was the focus of the study.

IV. CONCLUSIONS

A. CONCLUSIONS

This project proved that data marked with a higher priority have a higher transmission rate when placed through a prioritized queue. Using ExtendSim7™ modeling and statistical analysis, the reasonable conclusion could be drawn that the average transmission time for a given data category will decrease based on the priority level assigned to it as long as other packets exist with a lower priority. Thus, the prioritization methodology proposed would yield improved data throughput under congested conditions.

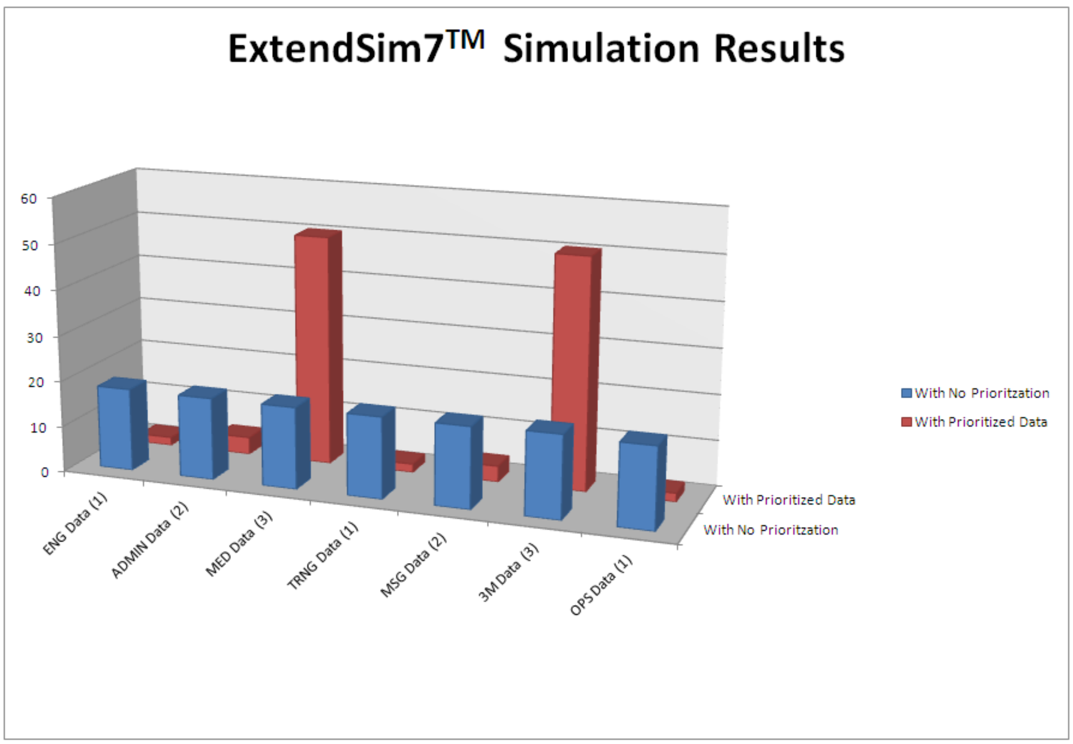

Figure 29. ExtendSim7™ Simulation Results

The figure shows the simulation results of the ExtendSim7™ model comparing both with no prioritization and with prioritized data.

Simulating the shipboard ADNS infrastructure using JCSS, it was determined that the size and periodicity of application packets would not cause a backlog of data when the ship has constant connectivity. In other words, the JCSS simulation, which assumes ideal shipboard communication conditions, produced no congestion in the data categories of interest and thus no throughput improvements were realized. This was consistent with expectations based on interviews with SMEs and others having knowledge of shipboard operations. However, ships do not often operate under ideal communication conditions. For example, ships operating in high concentration areas have to share limited satellite resources. As a result, ships are given small satellite connectivity windows during which time environmental factors such as heavy seas or adverse weather can cause periodic loss of connectivity. Furthermore, a ship‟s mission may sometimes necessitate a heading resulting in the mast or superstructure interfering with the direct line of sight between the antenna and satellite thus negatively impacting connectivity while this situation persists. Losses in connectivity on a regular basis result in a backlog of data waiting to get off the ship. Therefore, we conclude that when a ship is under intermittent connectivity, the implementation of data marking, prioritizing, and prioritized queuing would effectively allow COs the ability to get their highest priority data off their ships in a far more effective manner.

B. RECOMMENDATIONS AND AREAS FOR FURTHER STUDY

As the project team learned during the stakeholders and need analysis, ship-to-shore data prioritization is an important subject to address. In fact, the Navy‟s technical community has been trying to address this for several years now. Although the ADNS community has been striving to improve its prioritization capabilities from a technical (implementation/solution) standpoint, a higher level and wider effort should be undertaken in order to define ship-to-shore data prioritization requirements from a functional perspective. The ADNS community seems to be longing for this, a "framework", as one of the stakeholders described it, in which they can work with. Such an effort (e.g., stakeholders functional requirements Integrate Product Team (IPT)) would be theater wide, bringing in elements from various war fighter user communities, and eliciting high level functional requirements from them.

Based on the results of the theater wide stakeholders functional requirements IPT recommended above, develop the user interface application that would employ the prioritization matrix described in this project. This would give the CO the capability to select and prioritize data based on the ship‟s operational situation, before the data leave the ship.

Another recommendation that could minimize user effort and improve automation and modularity is to develop an automated interface service for the network to receive prioritization information from external application sources. An external application example is the user interface recommended above. This service would translate the prioritization information from external application sources into QoS policies and other mechanisms to actually implement prioritization within the network. This service would allow modularity, interoperability, flexibility, and would allow dynamic changes in receiving prioritization information from various sources and driving the network prioritization. To illustrate the need for this automated interface service, consider the current ADNS prioritization capability. The current ADNS prioritization interface, that which receives prioritization information from the user for the network to employ, is problematic. This is the main reason why ADNS‟ current prioritization capability is not widely used.

A business process reengineering may have to be conducted. This would eliminate the status quo in which prioritization is done mainly ashore and in an ad-hoc manner. Once the framework is in place and prioritization is fully implemented on the ship, performing prioritization ashore also could cause data conflicts.

As discussed during the project meetings between the team and its advisors, the work that have been started in this project and the recommendations could be continued and further developed by other/future NPS masters and/or doctoral efforts. Such undertaking could continue to parallel the work by the ADNS and IT community and would benefit the Navy as a whole.

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APPENDIX A. ARCHITECTURE

A. ARCHITECTURE

1. Operational Activity Decomposition Tree (OV-5a)

The Capstone Operational Activity Decomposition Tree (OV-5a) as shown in Figure 30 displays the capabilities and activities of the architecture organized in a hierarchal structure. The OV-5a helps provide an overall picture of the activities involved and a quick reference for navigating the OV-5b. Operational activities are derived from the Universal Naval Task List (UNTL).

The OV-5 describes the operations that are conducted in the course of achieving a mission capability from a typical USN afloat vessel underway. The operational activities focus on the activities previously shown in the prioritization matrix (which are AD, JTMD, strike, NSFS, MIO, humanitarian support, MCM, ASW, SUW, INTEL, transit, and off station. The activities are further decomposed based on their pedigree in the doctrinal documents previously mentioned in this paragraph.

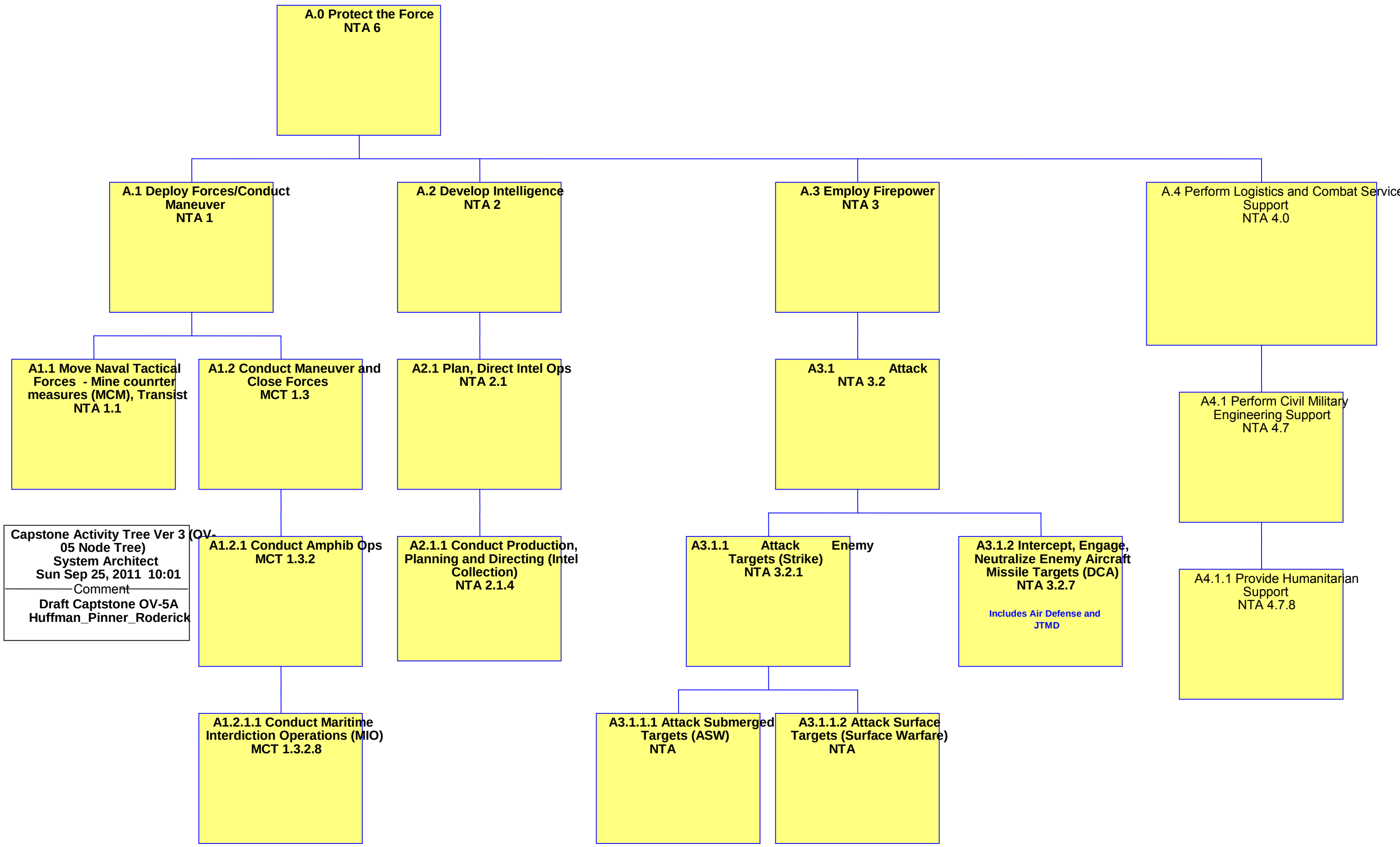


Figure 30. Operational Activity Decomposition Tree (OV-5a)

The OV-5 describes the operations that are conducted in the course of achieving a mission capability from a typical USN afloat vessel underway.

2. Operational Activity Model (OV-5b)

The Capstone OV-5 Model depicts the Joint Capabilities Area (JCA) in the context of the high level operational activities conducted by the Ship. The focus of the model is the routing of data as prioritized by the operators for a specific mission. This model provides the framework for the ship conduct of JCAs that are mapped throughout this model. The Ship provides the Joint Task Force (JTF) Commander with the following operational capabilities: force support, battlespace awareness, force application, command and control, net-centric and protection

Inputs and outputs of operational activities relate to information elements of the OV-3. The activities identified in the OV-5 are also directly traceable to the OV-3. The activities from the OV-5 relate indirectly to the functionality of the ship through a mapping of activities to system functions derived from the Joint Common System Function List (JCSFL). Normally this association is contained in the SV-5. The ship will support these activities by either automating them directly or by supporting them by providing automated tools. It must be noted that the activities are from an authoritative data source, specifically the naval activity list. A graphical depiction of the activity relationship in a node tree and then in Integration Definition (IDEF0) format is provided. The activity model context diagram is provided in Figure 31 and the IDEF0 decomposition down to the leaf level activities are also provided in Figure 32 and Figure 33.

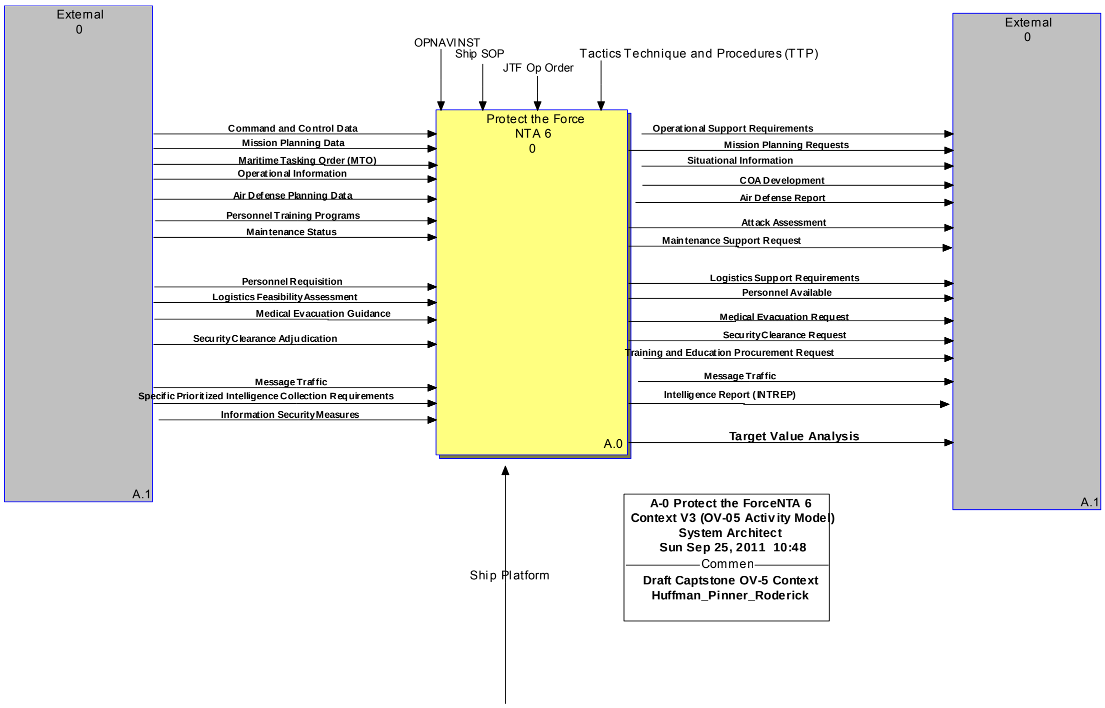


Figure 31. A-0 Context Diagram

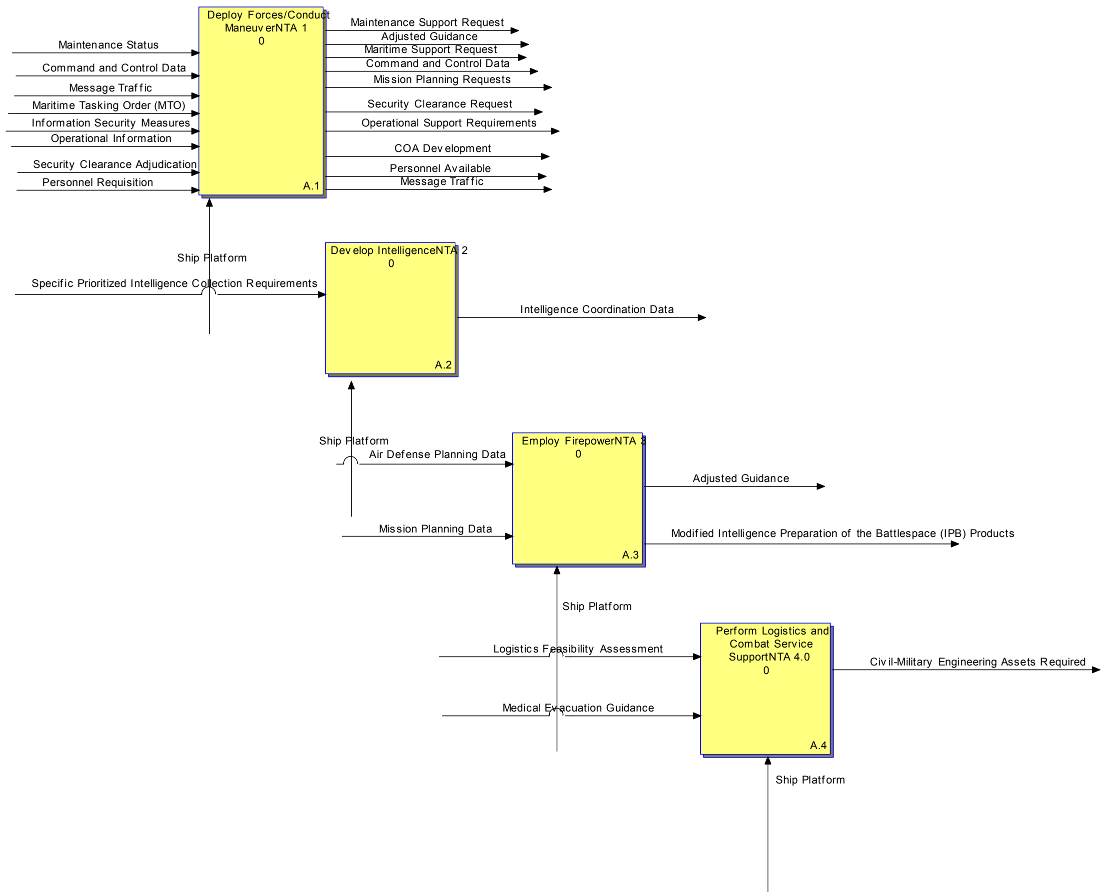
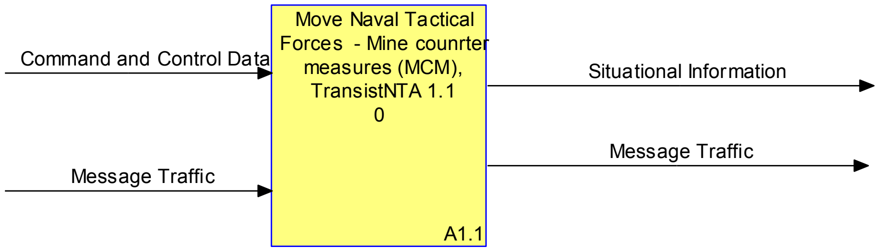
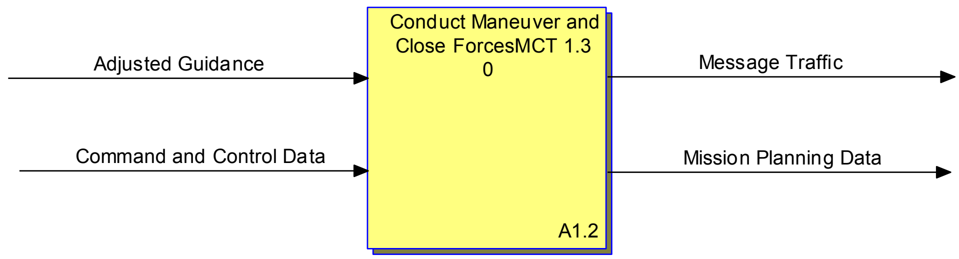
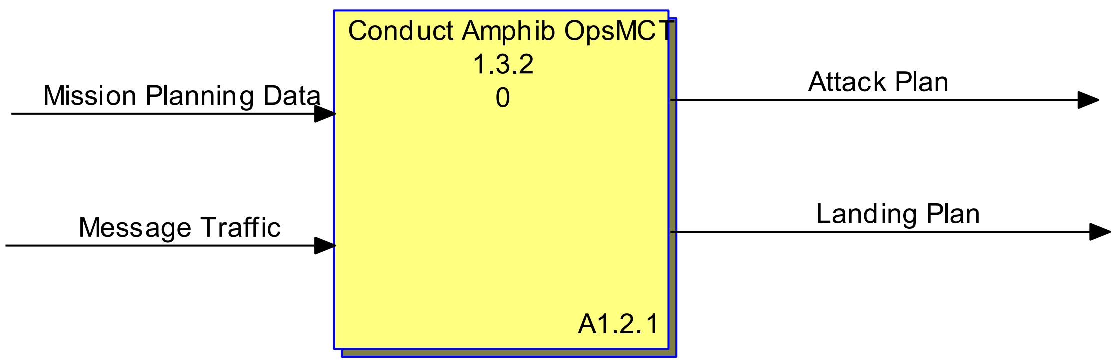
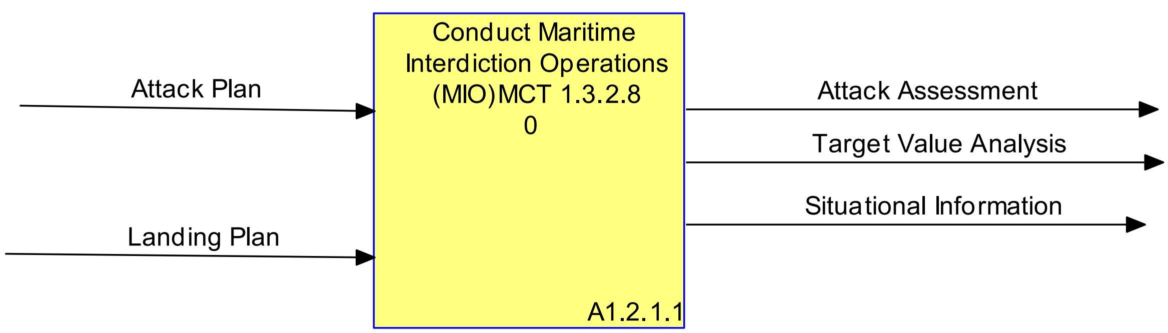


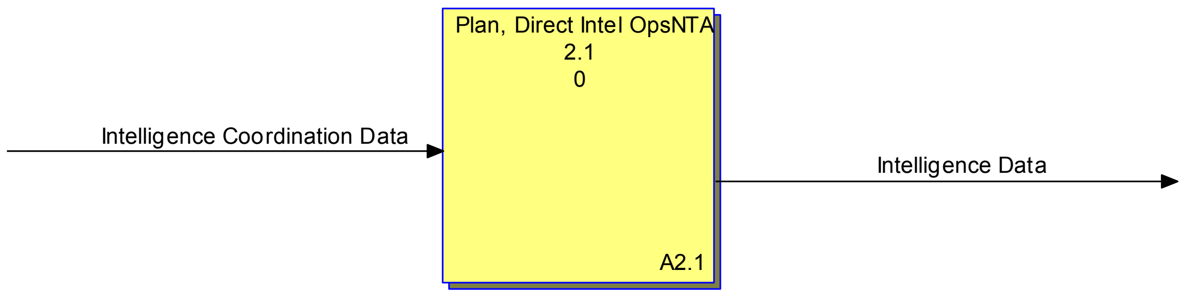
Figure 32. A0 Decomposition Diagram

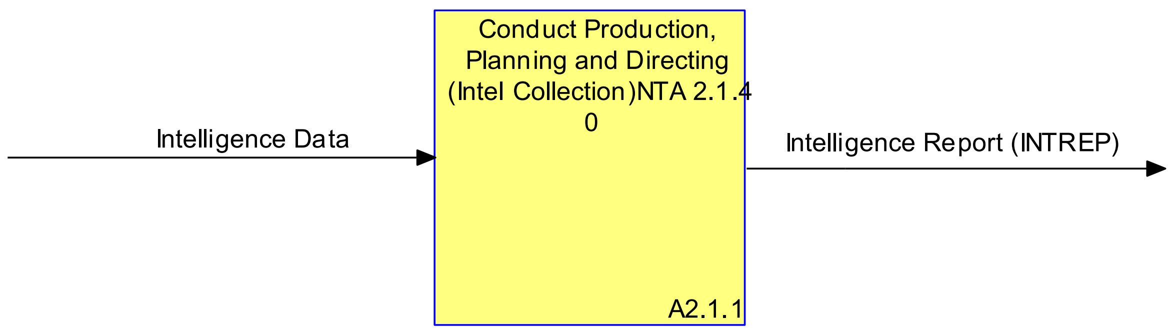

Move Naval Tactical Forces - Mine counrter measures (MCM), TransistNTA 1.1
0
A1.1
Command and Control Data
Message Traffic
Situational Information
Message Traffic

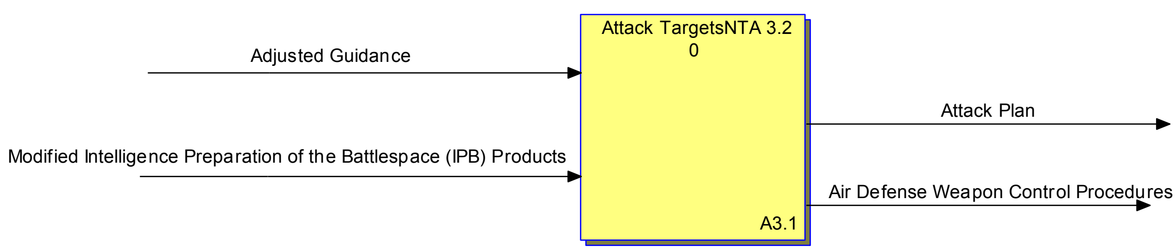

Conduct Maneuver and Close ForcesMCT 1.3
0
A1.2
Adjusted Guidance
Command and Control Data
Message Traffic
Mission Planning Data

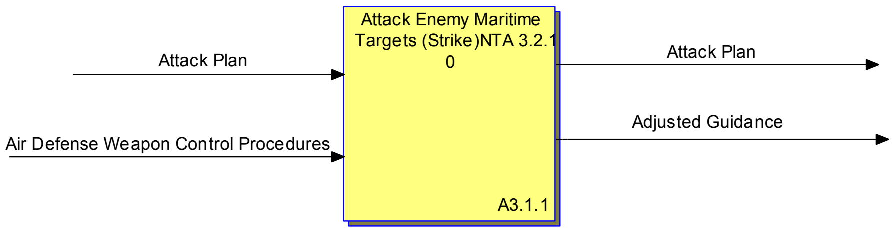

Conduct Amphib OpsMCT 1.3.2
0
A1.2.1
Mission Planning Data
Message Traffic
Attack Plan
Landing Plan

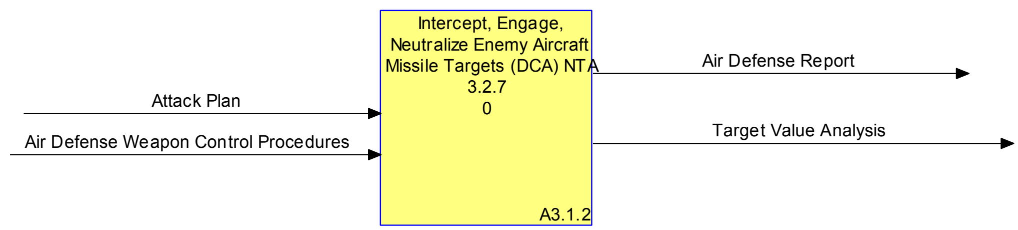

Conduct Maritime Interdiction Operations (MIO)MCT 1.3.2.8
0
A1.2.1.1
Attack Plan
Landing Plan
Attack Assessment
Target Value Analysis
Situational Information

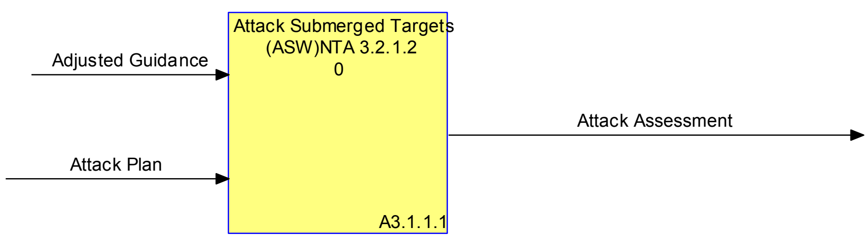

Plan, Direct Intel OpsNTA 2.1
0
Intelligence Coordination Data
Intelligence Data
A2.1

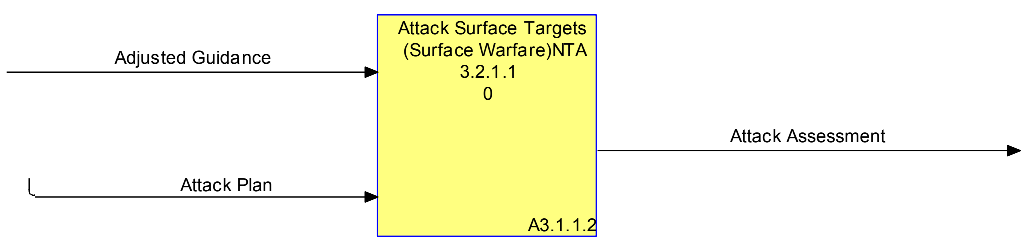

Conduct Production, Planning and Directing (Intel Collection)NTA 2.1.4
0
Intelligence Data
Intelligence Report (INTREP)
A2.1.1

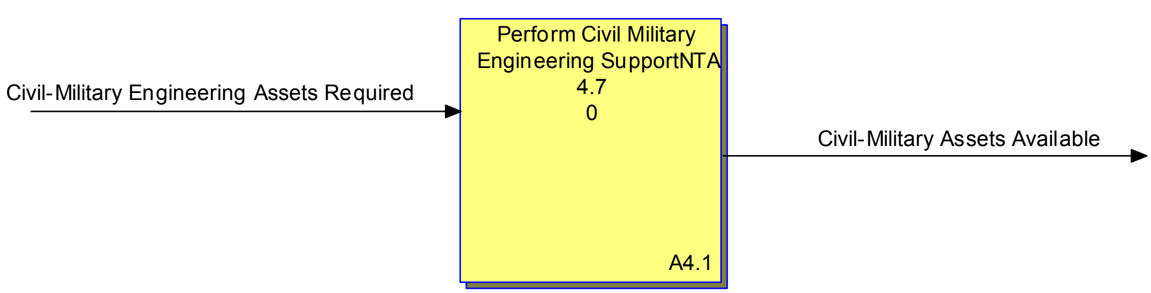

Attack TargetsNTA 3.2
0
Adjusted Guidance
Modified Intelligence Preparation of the Battlespace (IPB) Products
Attack Plan
Air Defense Weapon Control Procedures
A3.1


Attack Enemy Maritime Targets (Strike)NTA 3.2.1
0
A3.1.1
Attack Plan
Air Defense Weapon Control Procedures
Attack Plan
Adjusted Guidance


Intercept, Engage, Neutralize Enemy Aircraft Missile Targets (DCA) NTA 3.2.7
0
A3.1.2
Attack Plan
Air Defense Weapon Control Procedures
Air Defense Report
Target Value Analysis


Attack Submerged Targets (ASW)NTA 3.2.1.2
0
A3.1.1.1
Adjusted Guidance
Attack Plan
Attack Assessment


Attack Surface Targets (Surface Warfare)NTA 3.2.1.1
0
A3.1.1.2
Adjusted Guidance
Attack Plan
Attack Assessment


Perform Civil Military Engineering SupportNTA 4.7
0
A4.1
Civil-Military Engineering Assets Required
Civil-Military Assets Available

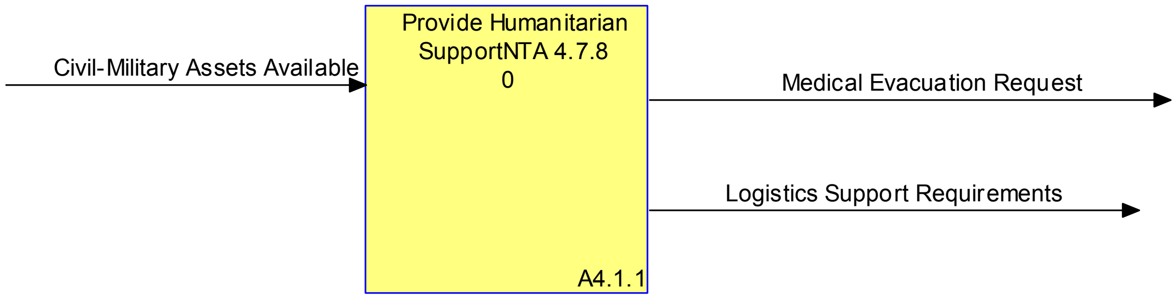


Figure 33. Leaf Level Activity Decompostion

5. Operational Information Exchange Matrix (OV-3)

The information exchanged, characteristics, and associated activities performed by the ship that support the JCA are outlined within the OV-3.

The ship OV-3 identifies information elements and relevant attributes of the information exchanged while providing activities for JCAs; then, associates the information exchanges to the producing and consuming operational nodes for the activities to the need-line that the exchange is transmitted upon. The OV-3 documents the information exchanged and the characteristics (description, attributes, security, etc.) for each of the exchanges. The OV-3 details information exchanges and identifies "who exchanges what information, with whom, why the information is necessary, and how the information exchange must occur." [CJCSI 6212.01E, 2008]. There is not a one-to-one mapping of OV-3 information exchanges to OV-2 need-lines; rather, many individual information exchanges are associated with one need-line. The OV-3 identifies information elements and relevant attributes of the information exchange associated with a need-line between producing and consuming operational nodes in the OV-2 while conducting activities contained within the OV-5.

Need Line	Information	Source Node	Source Activity	Destination Node	Destination Activity
NL-7 (Operations App Data Source to Ship Platform)	Command and Control Data	Operations Application Data Source	External	Ship Platform	Protect the ForceNTA 6 Deploy Forces/Conduct ManeuverNTA 1 Move Naval Tactical Forces - Mine counrter measures (MCM), TransistNTA 1.1 Conduct Maneuver and Close ForcesMCT 1.3
	Mission Planning Data	Operations Application Data Source	External	Ship Platform	Protect the ForceNTA 6 Employ FirepowerNTA 3 Conduct Amphib OpsMCT 1.3.2
	Operational Information	Operations Application Data Source	External	Ship Platform	Protect the ForceNTA 6 Deploy Forces/Conduct ManeuverNTA 1
	Security Clearance Adjudication	Operations Application Data Source	External	Ship Platform	Protect the ForceNTA 6 Deploy Forces/Conduct ManeuverNTA 1
NL-8 (Ship Platform to Operations Application Data Source)	Operational Support Requirements	Ship Platform	Deploy Forces/Conduct ManeuverNTA 1	Operations Application Data Source	External
	Mission Planning Request	Ship Platform	Protect the ForceNTA 6 Deploy Forces/Conduct ManeuverNTA 1	Operations Application Data Source	External
	COA Development	Ship Platform	Deploy Forces/Conduct ManeuverNTA 1	Operations Application Data	External
	Security Clearance Request	Ship Platform	Protect the ForceNTA 6 Deploy Forces/Conduct ManeuverNTA 1	Operations Application Data Source	External
NL-4 (Ship Platform to Msg App Data Source)	Message Traffic	Ship Platform	Move Naval Tactical Forces - Mine counrter measures (MCM), TransistNTA 1.1 Deploy Forces/Conduct ManeuverNTA 1 Conduct Maneuver and Close ForcesMCT 1.3	Message Traffic Application Source	External
	Intelligence Report (INTREP)	Ship Platform	Protect the ForceNTA 6 Conduct Production, Planning and Directing (Intel Collection)NTA	Message Traffic Application Source	
	Situational Information	Ship Platform	Move Naval Tactical Forces - Mine counrter measures (MCM), TransistNTA 1.1 Conduct Maritime Interdiction Operations (MIO)MCT 1.3.2.8	Message Traffic Application Source	External
	Air Defense Report	Ship Platform	Intercept, Engage, Neutralize Enemy Aircraft Missile Targets (DCA) NTA 3.2.7	Message Traffic Application Source	External

Figure 34. Operational Information Exchange Matrix (OV-3)

Need Line	Information	Source Node	Source Activity	Destination Node	Destination Activity
	Target Value Analysis	Ship Platform	Protect the ForceNTA 6 Intercept, Engage, Neutralize Enemy Aircraft Missile Targets (DCA) NTA 3.2.7 Conduct Maritime Interdiction Operations (MIO)MCT 1.3.2.8	Message Traffic Application Source	External
	Attack Assessment	Ship Platform	Protect the ForceNTA 6 Attack Surface Targets (Surface Warfare)NTA 3.2.1.1 Attack Submerged Targets (ASW)NTA 3.2.1.2 Conduct Maritime Interdiction Operations (MIO)MCT 1.3.2.8	Message Traffic Application Source	External
NL-3 (Msg Traffic App Data Source to Ship Platform)	Message Traffic	Message Traffic Application Source	External	Ship Platform	Protect the ForceNTA 6 Deploy Forces/Conduct ManeuverNTA 1 Move Naval Tactical Forces - Mine counrter measures (MCM), TransistNTA 1.1 Conduct Amphib OpsMCT 1.3.2
	Specific Prioritized Intelligence Collection	Message Traffic Application Source	External	Ship Platform	Protect the ForceNTA 6 Develop IntelligenceNTA 2
	Maritime Tasking Order (MTO)	Message Traffic Application Source	External	Ship Platform	Deploy Forces/Conduct ManeuverNTA 1
	Air Defense Planning Data	Message Traffic Application Source	External	Ship Platform	Protect the ForceNTA 6 Employ FirepowerNTA 3
	Information Security Measures	Message Traffic Application Source		Ship Platform	Protect the ForceNTA 6 Deploy Forces/Conduct ManeuverNTA 1
NL-13 (Ship Platform to Training App Data Source)	Training and Education Procurement	Ship Platform		Training Application Data Source	External
NL-14 (Training App Data Source to Ship Platform)	Personnel Training Programs	Training Application Data Source		Ship Platform	Protect the ForceNTA 6
NL-1 (Medical Info Data Source to Ship	Medical Evacuation Guidance	Medical Info Data Source		Ship Platform	Protect the ForceNTA 6
NL-2 (Ship Platform to Medical Info Data Source)	Medical Evacuation Request	Ship Platform	Protect the ForceNTA 6	Medical Info Data Source	External
NL- 5(Admin App data to Ship Platform)	Personnel Requisition	Admin Application Data Source		Ship Platform	Protect the ForceNTA 6 Deploy Forces/Conduct ManeuverNTA 1
NL-6 (Ship Platform to Admin App Data Source)	Personnel Available	Ship Platform	Protect the ForceNTA 6 Deploy Forces/Conduct ManeuverNTA 1	Admin Application Data Source	External

Figure 35. Operational Information Exchange Matrix (OV-3)

Need Line	Information	Source Node	Source Activity	Destination Node	Destination Activity
NL-16 (Engineering App Data Source to Ship Platform)	Logistics Feasibility Assessment	Engineering Application Data Source	External	Ship Platform	Protect the ForceNTA 6
NL-15 (Ship Platform to Engineering App Data Source)	Logistics Support Requirements	Ship Platform	Protect the ForceNTA 6	Engineering Application Data Source	External
NL-9 (3M App Data Source to Ship Platform)	Maintenance Status	3M App Data Source	External	Ship Platform	Protect the ForceNTA 6 Deploy Forces/Conduct ManeuverNTA 1
NL-10 (Ship Platform to 3M App Data Source)	Maintenance Support Request	Ship Platform	Protect the ForceNTA 6 Deploy Forces/Conduct ManeuverNTA 1	3M App Data Source	

Figure 36. Operational Information Exchange Matrix (OV-3)

6. Capability to Operational Activities Mapping (CV-6)

The Capability to Operational Activities Mapping (CV-6) identifies capabilities and the associated operational activities required for a typical USN afloat vessel underway and in port. In order to understand the information exchanges and related services that describe information sharing capabilities, a CV-6 As-Is and CV-6 To-Be view was developed. The As-Is view depicts the current state of a typical USN afloat vessel underway and in port and the To-Be view depicts the future once a prioritization scheme is incorporated into a typical USN afloat vessel underway and in port.

The operational activities shown are derived from the mission areas that the ship will participate in and are sourced from the UNTL publications. The capabilities are sourced from the JCA dated January 12, 2009. The JCAs are Department of Defense (DoD) capabilities functionally grouped to support capability analysis, strategy development, investment decision making, capability portfolio management, and capabilities-based force development and operational planning. An "X" in the cell indicates that full functionality is provided, supporting the activity. A blank cell indicates that there is no capability support planned for an operational activity, or that a relationship does not exist between the operational activity and the capability.

Table 11. Capability to Operational Activities Mapping (CV-6) As-Is

	Activities / Capabilities	A3.1.2 Intercept, Engage, Neutralize Enemy Aircraft Missile Tragets -Air Defense (AD) & JTMD NTA 3.2.7	Strike NTA 3.2.1	A3.1.3 Coduct Fire Support-Naval Surface Fire Support (NSFS)	A1.2.1.1 Conduct Maritime Interdiction Operations (MIO) MCT 1.3.2.8	A1.1 Move Naval Tactical Forces-Mine Counter Measures (MCM), Transist NTA 1.1	A3.1.1.1 Attack Submerged Targets (ASW) NTA 3.2.1.2	A3.1.1.2 Attack Surface Targets (Surface Warfare) NTA 3.2.1.1	Humanitarian Operations NTA 4.7.8	A2.1.1 Conduct Production, Planning and Direction (Intelligence Collecton (INTEL) NTA 2.1.4
1.0 Force Support	1.1 Force Management	X	X	X	X	X	X	X	X	X
	1.2 Force Preparation									X
2.0 Battlespace Awareness	2.1 Intelligence, Surveillance and Reconnaissance									X
	2.2 Environment	X	X				X	X		
3.0 Force Application	3.2 Engagement	X	X	X			X	X		
	3.1 Maneuver	X	X	X		X	X	X		
4 Logistics	4.1 Deployment and Distribution	X			X	X				X
5.0 Command & Control	5.2 Understand	X	X	X	X	X	X	X		X
	5.3 Planning	X	X	X	X	X	X	X		X
	5.4 Decide	X	X	X	X	X	X	X		X
	5.5 Direct	X	X	X	X	X	X	X		X
	5.6 Monitor	X	X	X	X	X	X	X		X
6.0 Net-Centric	6.1 Information Transport (IT)	X	X	X	X	X	X	X		X
	6.2 Enterprise Services (ES)	X	X	X	X	X	X	X		X
	6.3 Information Assurance	X	X	X	X	X	X	X		X
7.0 Protection	7.1 Prevent					X				

Table 12. Capability to Operational Activities Mapping (CV-6) To-Be

	Activities Capabilities	A3.1.2 Intercept, Engage, Neutralize Enemy Aircraft Missile Tragets -Air Defense (AD) & JTMD NTA 3.2.7	Strike NTA 3.2.1	A3.1.3 Coduct Fire Support-Naval Surface Fire Support (NSFS)	A1.2.1.1 Conduct Maritime Interdiction Operations (MIO) MCT 1.3.2.8	A1.1 Move Naval Tactical Forces-Mine Counter Measures (MCM), Transist NTA 1.1	A3.1.1.1 Attack Submerged Targets (ASW) NTA 3.2.1.2	A3.1.1.2 Attack Surface Targets (Surface Warfare) NTA 3.2.1.1	Humanitarian Operations NTA 4.7.8	A2.1.1 Conduct Production, Planning and Directiong (Intelligence Collecton (INTEL) NTA 2.1.4
1.0 Force Support	1.1 Force Management	X	X	X	X	X	X	X		X
	1.2 Force Preparation									X
2.0 Battlespace Awareness	2.1 Intelligence, Surveillance and Reconnaissance									X
	2.1.1.1 Define and Prioritize Intelligence, Surveillance and Reconnaissance Requirements									X
	2.2 Environment	X	X				X	X		
3.0 Force Application	3.2 Engagement	X	X	X			X	X		
	3.1 Maneuver	X	X	X		X	X	X		
5.0 Command & Control	5.2 Understand	X	X	X	X	X	X	X		X
	5.1.2.5 Establish Commander's Expectations	X	X	X	X	X	X	X		X
	5.3 Planning	X	X	X	X	X	X	X		X
	5.4 Decide	X	X	X	X	X	X	X		X
	5.5 Direct	X	X	X	X	X	X	X		X
	5.5.1.2 Issue Priorities	X	X	X	X	X	X	X		X
	5.6 Monitor	X	X	X	X	X	X	X		X
6.0 Net-Centric	6.1 Information Transport (IT)	X	X	X	X	X	X	X		X
	6.2 Enterprise Services (ES)	X	X	X	X	X	X	X		X
	6.3 Information Assurance	X	X	X	X	X	X	X		X
	6.3.1.2 Rapid Configuration Change	X	X	X	X	X	X	X		X
7.0 Protection	7.1 Prevent					X				
9.0 Corporate Management and Support	9.2 Strategy and Assessment	X		X	X	X				X

7. Systems Interface Description (SV-1)

The Systems Interface Description (SV-1) depicts systems nodes and the systems resident at these nodes to support organizations/human roles represented by operational nodes of the Operational Node Connectivity Description (OV-2). SV-1 also identifies the interfaces between systems and systems nodes.

SV-1 graphical depiction shown below provides an overview of the systems and identifies the resource flows from a typical USN afloat vessel underway and in port. As in the OV-2, it's understood that these generic nodes might actually breakout into multiple nodes however to reduce the time required for research and the overall complexity of the SV-1 the decision was made to use generic subject nodes.

Two SV-1 views were developed; a SV-1 As-Is and SV-1 To-Be. The As-Is view depicts the current state of a typical USN afloat vessel underway and in port and the To-Be view depicts the future once a prioritization scheme is incorporated into a typical USN afloat vessel underway and in port.

The black box depicts the focus of the capstone projects the will prioritize data before entering the ADNS.

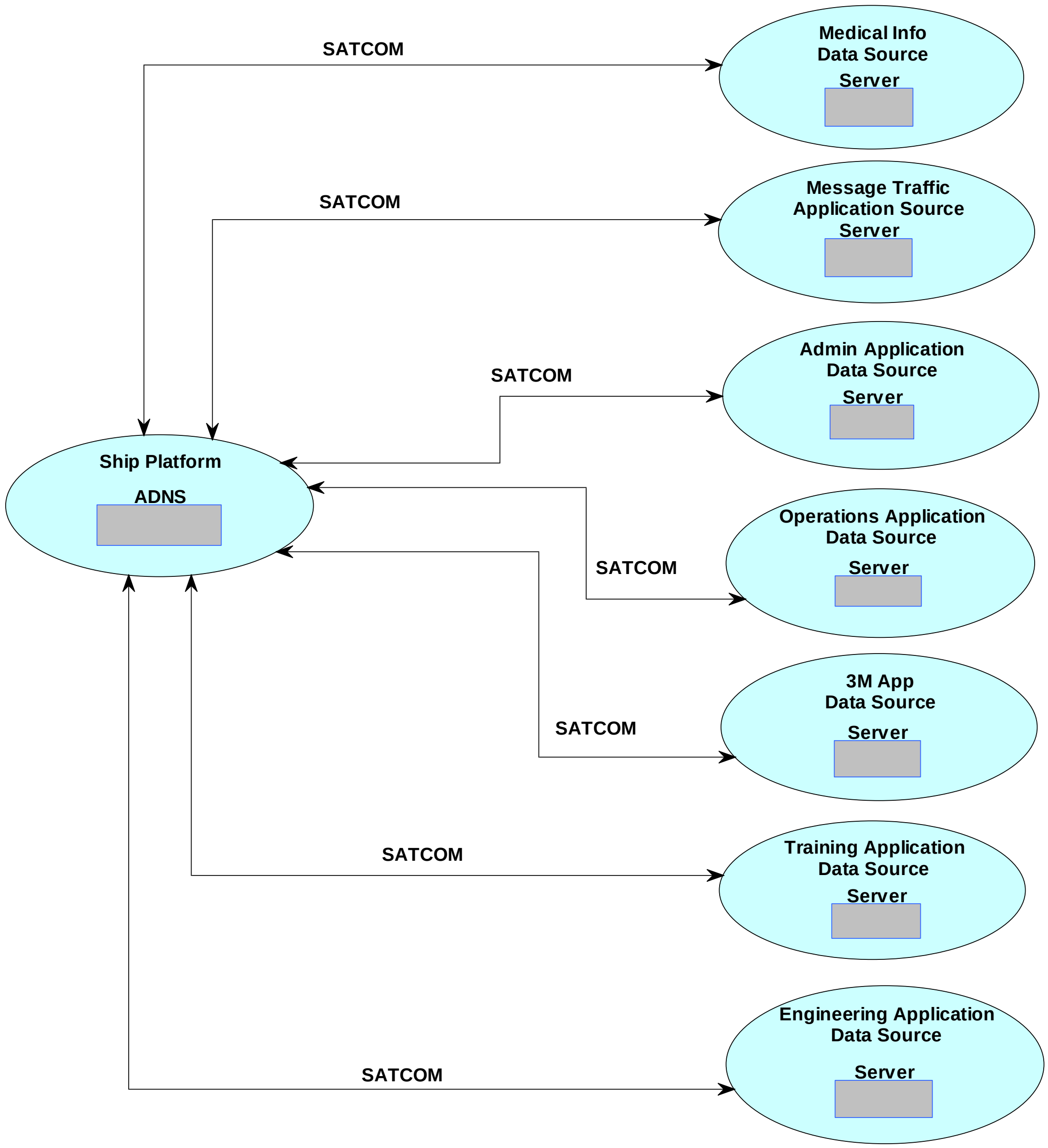


Figure 37. Systems Interface Description (SV-1) As-Is

SV-1 identifies the interfaces between systems and systems nodes.

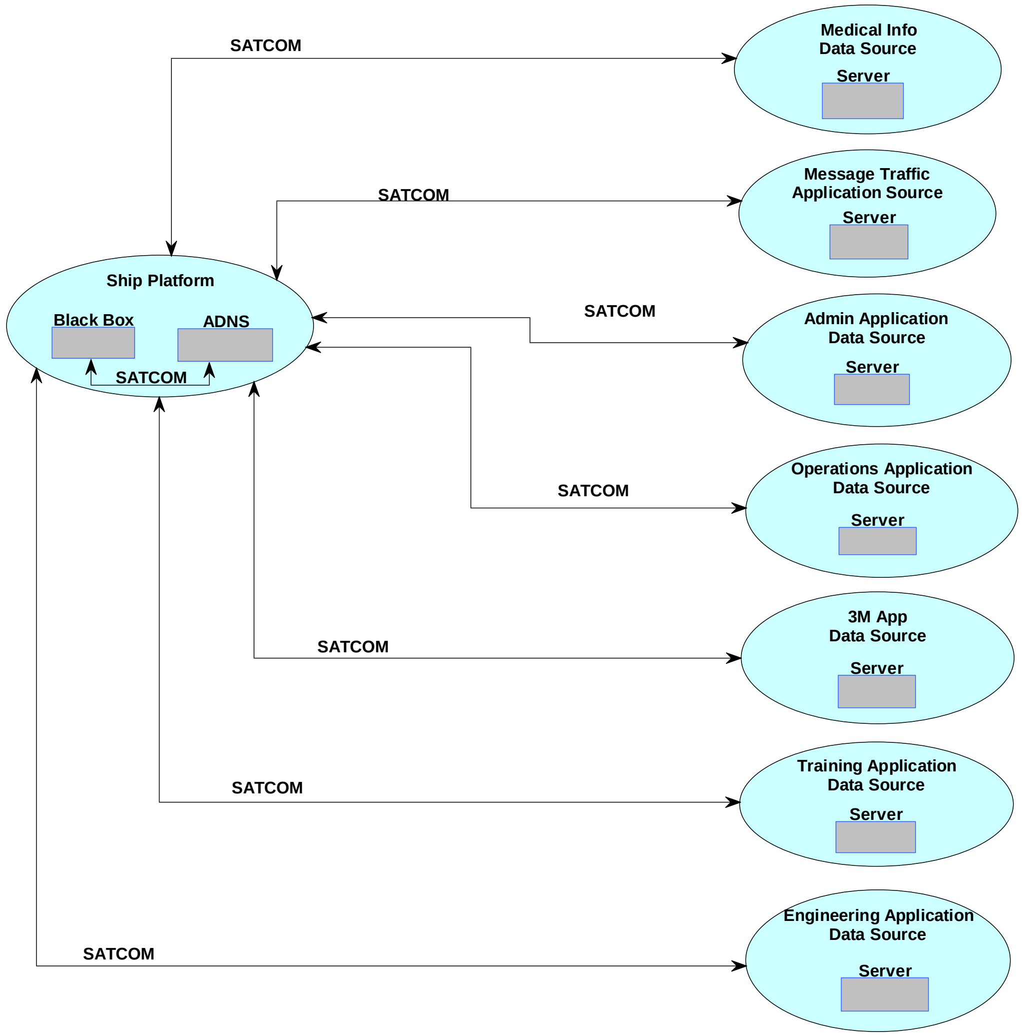


Figure 38. Systems Interface Description (SV-1) To-Be

SV-1 identifies the interfaces between systems and systems nodes.

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APPENDIX B. MODELING AND SIMLUATION

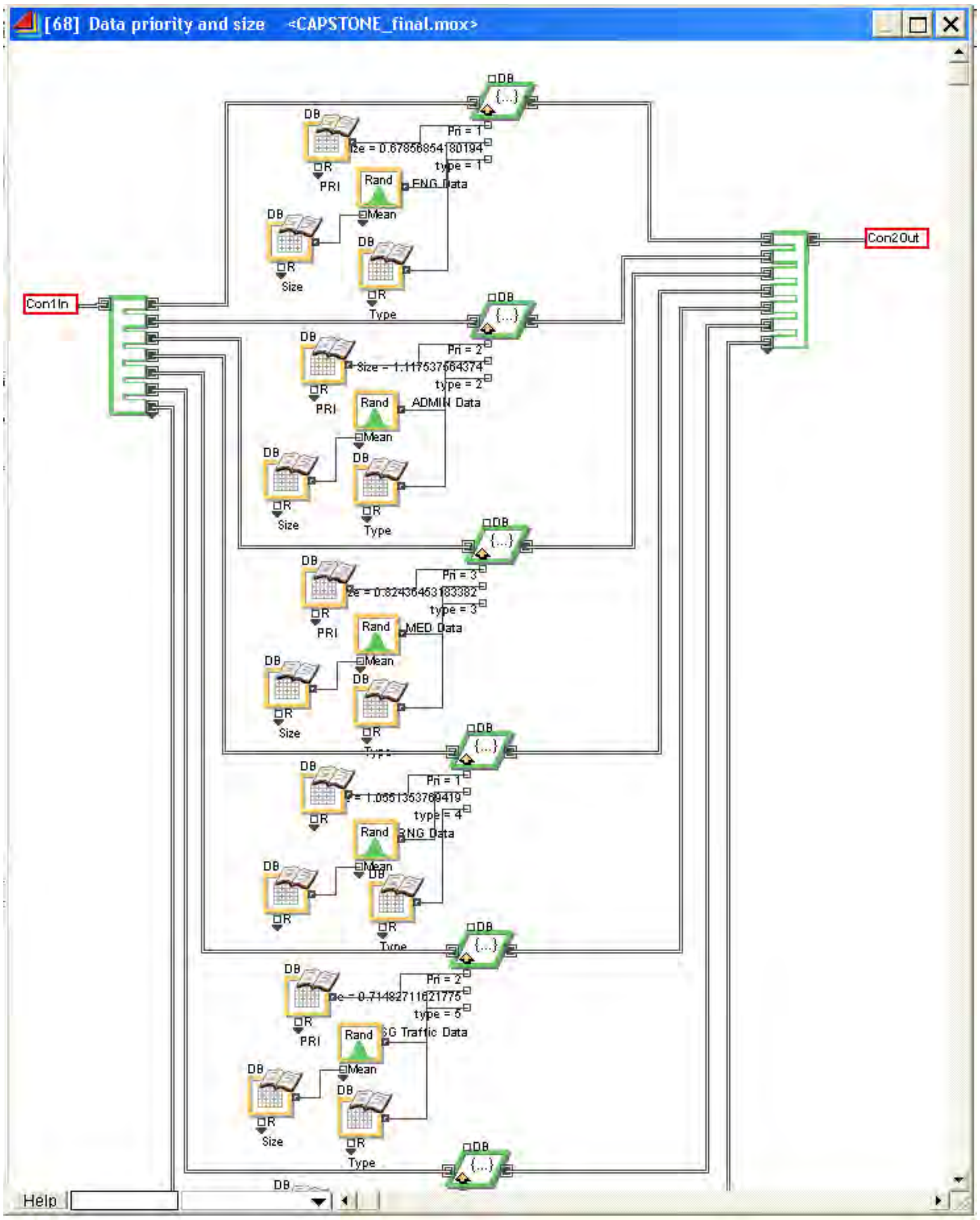

Figure 39. Priority, Size, and Data Types Assigned

Table 13. Data collected for no priority applied

No priority applied - Transmission time Data for 100 runs
First In - First Out

Data Type	ENG Data	ADMIN Data	MED Data	TRNG Data	MSG Data	3M Data	OPS Data
	13.455	14.684	7.152	6.836	15.785	12.372	7.535
	2.897	7.404	7.124	2.259	4.582	1.988	2.136
	19.287	12.407	12.811	13.232	14.057	17.499	18.050
	5.252	4.555	8.165	18.499	5.722	3.685	3.323
	34.160	34.849	34.735	29.736	29.969	33.809	31.648
	34.522	33.060	30.328	33.923	33.043	36.199	35.111
	17.881	17.737	16.627	16.210	16.768	18.142	17.717
	3.200	2.959	0.895	3.045	3.015	3.410	3.481
	44.325	44.276	44.314	44.915	43.339	44.999	44.078
	19.693	20.442	19.782	20.873	21.078	21.071	20.991
	29.497	30.284	29.627	29.436	26.373	28.563	28.912
	32.125	31.640	31.768	32.370	32.577	34.626	34.423
	4.517	1.674	3.782	4.279	1.617	1.051	2.172
	24.557	21.017	27.691	21.378	20.229	22.561	22.880
	22.868	17.765	17.640	18.785	18.738	24.100	18.373
	3.207	2.597	3.818	3.646	2.408	1.594	3.865
	6.915	7.519	6.782	6.861	7.268	6.991	7.289
	26.791	29.458	29.144	30.212	26.684	26.493	28.685
	5.649	7.359	7.423	8.383	7.333	6.396	6.184
	12.824	12.776	12.115	11.617	11.784	12.333	12.319
	42.072	40.576	41.773	40.900	41.493	41.840	42.464
	35.218	34.416	31.773	32.696	38.158	32.119	33.597
	19.842	18.092	18.661	16.626	16.950	18.094	14.853
	25.293	23.293	24.499	25.257	23.508	25.309	26.106
	2.876	1.914	1.419	1.916	2.285	1.104	1.096
	18.040	18.687	19.701	22.153	19.318	19.583	18.220
	7.684	5.969	8.302	5.835	6.134	7.487	6.794
	4.059	3.910	6.145	4.493	3.497	2.470	4.990
	30.529	21.438	29.656	28.314	29.463	28.289	30.434
	22.238	22.840	15.378	15.367	21.490	22.892	21.684
	3.605	5.906	3.956	5.062	4.714	4.402	5.525
	23.009	30.040	31.361	31.644	32.152	30.485	23.878
	9.007	8.749	9.232	7.854	5.309	8.955	8.520
	35.379	34.695	34.658	34.716	34.495	34.036	35.124
	28.845	29.412	29.582	29.047	30.448	29.637	28.919

21.542	22.413	19.672	21.386	22.582	19.403	20.558
15.388	16.271	12.371	14.213	13.773	14.625	13.341
35.776	37.857	37.524	36.220	37.075	37.357	37.326
20.884	22.007	21.528	22.054	21.985	19.808	21.430
17.211	19.188	18.087	19.313	17.120	18.825	17.655
29.905	29.029	30.904	30.328	30.777	30.017	30.379
23.570	24.273	23.909	19.849	20.633	24.177	21.325
0.691	2.298	0.913	2.499	0.903	2.511	1.757
15.279	16.836	12.598	14.531	14.776	11.852	16.033
3.953	1.500	1.645	0.688	1.159	3.110	3.524
9.793	8.487	8.370	9.069	7.935	8.857	9.151
12.476	11.387	11.215	12.282	11.977	13.618	8.766
6.818	8.496	13.124	8.444	7.900	7.584	7.997
25.019	25.476	25.120	25.101	26.667	27.565	25.518
18.364	21.386	22.071	21.469	26.316	20.397	19.460
23.520	22.541	24.242	23.697	23.654	23.022	22.295
22.487	22.966	21.042	21.556	17.919	22.705	18.143
15.325	14.485	10.756	14.083	16.672	15.620	16.401
22.735	22.661	19.708	22.462	17.667	24.007	24.298
8.875	8.281	7.996	7.434	8.056	9.397	6.685
22.384	21.842	24.079	21.756	22.913	22.474	22.320
9.020	7.284	7.167	9.150	7.704	6.032	6.622
13.881	11.463	11.416	11.632	14.442	12.108	15.174
12.393	10.162	10.905	10.168	12.371	9.438	11.633
10.354	13.096	12.581	13.902	11.199	13.747	9.624
20.017	12.946	20.654	11.214	13.659	12.516	12.155
41.681	40.698	41.441	40.733	37.063	29.807	40.958
5.888	5.127	5.996	5.486	6.072	12.573	6.404
19.876	21.364	18.198	22.665	18.907	20.256	20.875
11.292	9.895	12.978	13.866	11.861	13.122	8.628
36.215	35.051	35.009	32.089	38.125	38.750	38.518
8.010	8.571	9.366	9.845	3.652	8.124	8.007
21.946	24.435	23.987	23.147	23.053	28.520	23.910
9.674	11.606	10.694	12.178	10.639	10.869	12.242
22.499	20.747	21.907	22.740	19.946	21.950	20.555
43.321	40.879	42.817	36.240	40.279	43.214	40.377
29.169	29.436	29.173	26.444	28.312	25.422	28.769
26.916	30.929	28.949	25.923	30.007	30.656	30.331
3.204	1.864	0.778	1.038	0.898	6.843	0.971
37.987	39.270	37.512	37.119	44.844	36.134	39.092

	19.509	18.343	19.726	21.134	20.127	21.841	19.543
	1.063	1.940	1.249	0.977	1.236	1.323	2.056
	23.740	24.959	19.500	23.643	23.363	24.185	23.637
	10.065	6.565	8.088	8.741	7.658	5.981	7.947
	6.560	9.960	8.392	9.733	9.515	6.462	5.137
	10.402	9.246	9.725	9.301	10.918	11.370	11.414
	29.437	28.760	26.811	25.052	28.114	30.674	30.036
	7.327	7.580	6.133	8.178	3.790	8.520	6.415
	39.877	41.946	37.856	39.397	41.583	40.883	42.344
	16.540	26.432	27.179	26.187	27.464	24.169	27.614
	9.861	10.497	8.905	9.432	8.332	8.450	9.338
	3.105	1.018	2.734	10.701	4.599	3.994	2.935
	40.173	39.147	37.491	40.632	37.969	38.683	40.126
	10.511	4.237	11.395	10.878	11.011	9.960	7.401
	7.519	7.596	8.188	8.632	8.367	8.455	7.680
	21.170	21.467	22.132	22.169	21.499	21.402	21.873
	6.326	5.848	5.513	5.792	3.318	5.597	6.125
	3.532	6.146	3.254	2.605	4.356	4.260	2.354
	21.918	21.914	22.498	22.021	23.293	22.568	22.825
	7.509	8.093	6.739	5.309	4.549	5.939	4.997
	3.424	3.839	3.801	1.286	3.097	3.223	2.043
	4.220	1.804	2.135	0.894	2.560	1.050	4.133
	24.830	25.981	25.038	22.219	24.265	25.734	25.276
	38.177	37.653	38.449	38.357	38.882	40.215	39.086
	13.736	13.083	16.498	13.245	10.800	13.604	12.276
Average Trans time	18.072	17.930	17.856	17.789	17.739	18.101	17.752

Table 14. Data collected for priority sorting

Priority sorting - Transmission time Data for 100 runs

Data Type	ENG Data	ADMIN Data	MED Data	TRNG Data	MSG Data	3M Data	OPS Data
Priority	**1**	**2**	**3**	**1**	**2**	**3**	**1**
	1.494	4.739	16.589	1.045	1.440	26.929	1.797
	1.442	5.883	159.140	2.258	4.492	172.838	2.389
	3.121	1.786	48.653	1.124	2.826	72.410	2.449
	2.037	10.900	78.739	1.195	4.238	94.803	3.029
	1.284	11.037	42.868	1.387	1.582	43.491	1.443
	2.608	3.449	25.323	3.589	4.203	25.704	4.156
	1.687	2.584	56.462	1.874	2.689	46.081	2.197
	1.253	1.051	30.557	2.220	1.641	29.322	1.196
	1.204	3.753	84.519	1.664	5.961	77.277	1.232
	2.159	1.077	17.466	1.811	2.639	17.627	2.395
	1.156	1.620	4.245	1.496	0.902	1.093	1.813
	1.843	2.008	15.695	1.681	2.358	15.841	0.806
	1.612	2.000	123.662	0.990	1.568	121.734	1.296
	1.976	7.907	87.692	1.367	6.411	85.256	2.098
	0.955	0.776	3.422	1.566	1.776	6.677	1.277
	2.041	2.699	111.371	1.444	2.954	128.001	1.164
	2.128	1.414	28.086	1.194	2.468	29.295	2.065
	1.582	1.942	50.259	1.766	1.368	49.352	1.488
	1.831	1.178	63.553	1.321	1.578	71.041	0.831
	1.263	2.810	26.641	1.562	1.545	25.833	2.079
	3.277	3.527	6.535	2.956	7.994	5.238	1.852
	0.945	5.168	98.589	1.685	1.681	98.039	1.046
	2.128	1.916	123.095	2.182	4.414	124.172	1.234
	2.000	1.902	1.432	1.132	0.962	0.956	1.081
	1.468	4.313	27.608	1.018	6.286	8.921	1.538
	1.635	6.345	45.278	2.889	5.908	40.853	1.373
	2.232	3.309	12.488	1.293	3.275	13.194	3.713
	1.408	1.509	66.977	1.981	0.861	68.060	1.848
	1.945	10.075	7.820	3.157	9.085	1.991	5.555
	2.595	7.831	61.996	1.221	2.932	64.678	2.743
	2.365	2.984	1.530	1.451	2.302	3.569	0.944
	1.131	4.248	34.474	1.881	6.059	38.258	2.547
	2.439	1.638	34.421	1.716	1.497	36.495	2.124
	1.500	1.455	41.430	1.188	1.164	49.760	1.991
	3.557	5.719	62.371	4.344	1.144	62.908	2.854

1.887	12.613	73.751	2.673	2.509	72.180	1.639
1.720	2.083	36.201	2.037	2.371	49.082	0.562
0.946	1.378	1.458	0.970	1.293	2.495	1.826
2.470	1.189	95.666	0.983	5.225	76.936	0.877
1.463	2.417	53.399	1.422	1.091	46.111	1.131
1.283	6.944	33.628	1.720	1.534	34.100	1.558
1.553	6.622	93.792	1.122	6.956	78.903	3.787
0.949	3.968	101.826	1.606	5.194	102.237	1.882
2.802	1.562	57.050	0.808	5.268	64.447	1.855
2.278	5.849	82.390	3.126	3.014	81.213	2.325
0.770	1.085	2.096	2.127	1.641	4.205	0.967
2.022	1.590	48.488	3.018	1.868	47.680	1.827
1.845	1.086	26.752	1.254	1.346	26.704	2.406
1.484	2.902	167.749	2.805	1.705	170.248	1.850
1.202	3.525	52.045	1.534	3.940	52.259	2.085
1.781	4.341	35.548	2.370	3.626	33.534	2.163
1.882	10.119	39.300	1.244	0.958	39.636	1.626
2.224	16.186	154.801	3.694	10.641	175.368	1.630
3.423	1.579	109.634	1.379	1.669	101.278	3.546
2.058	4.387	72.724	0.976	6.463	72.296	1.101
1.887	1.543	96.035	1.121	1.817	98.951	1.996
2.576	7.770	14.351	0.993	5.314	27.277	1.692
2.255	1.036	72.794	1.048	1.273	68.644	1.351
1.300	1.353	2.944	1.293	1.367	3.503	1.213
1.067	4.442	16.924	3.768	4.064	31.799	3.111
1.722	2.599	44.456	1.602	3.548	53.211	1.603
1.351	1.659	8.237	1.537	1.825	7.991	1.700
1.223	2.859	1.261	1.428	1.467	2.302	1.236
0.751	1.740	43.130	2.083	3.936	41.788	2.243
1.826	3.284	30.700	1.914	5.210	22.539	2.303
2.612	7.789	134.283	1.449	8.176	68.995	1.912
1.648	1.800	3.603	1.265	1.485	21.082	2.039
2.121	3.035	54.268	1.829	5.736	57.279	1.045
3.321	6.330	56.576	1.691	5.308	53.792	2.049
0.962	9.759	1.030	2.361	10.921	2.961	1.516
2.480	1.833	36.483	2.283	3.248	37.253	1.302
1.658	5.470	19.587	4.586	3.113	19.358	1.506
2.112	1.821	22.794	1.721	3.024	11.815	1.600
1.850	4.298	3.608	2.538	2.379	0.624	1.410
1.544	1.271	1.036	0.756	3.436	1.498	1.833

	2.301	2.201	2.896	1.240	5.545	5.304	2.241
	1.086	2.234	51.518	0.941	1.837	48.580	0.875
	1.550	1.819	18.145	2.450	6.604	9.163	2.120
	1.303	3.327	29.363	1.341	1.449	33.396	2.122
	1.660	3.226	41.763	1.841	2.279	48.029	1.218
	1.201	0.645	86.008	1.336	2.648	79.602	1.625
	1.702	1.774	93.174	1.760	1.881	93.892	2.047
	1.074	2.458	45.982	2.165	3.064	57.693	2.924
	1.546	2.891	54.002	1.289	3.925	46.715	0.892
	1.048	7.349	65.082	2.822	1.309	68.002	0.900
	1.577	2.826	107.523	3.362	2.904	119.900	1.298
	1.024	1.747	37.016	1.918	11.730	37.350	2.893
	1.405	6.101	57.312	0.962	2.076	59.771	2.069
	1.450	2.554	90.387	2.827	1.137	90.721	1.746
	1.992	1.426	54.237	1.555	4.492	54.643	2.053
	2.155	5.437	7.502	2.366	9.127	8.874	1.803
	1.677	6.072	63.960	1.364	5.143	71.863	1.782
	1.836	1.729	55.890	1.269	2.873	59.179	1.756
	1.859	3.962	17.743	1.965	5.446	14.204	1.873
	1.890	5.907	180.797	1.304	5.123	158.914	1.889
	1.518	4.405	63.572	4.247	3.144	62.726	1.557
	2.567	2.719	15.584	1.210	1.217	6.551	3.120
	1.830	1.624	2.470	1.240	0.894	3.919	1.812
	2.132	3.786	51.504	1.833	3.260	51.218	1.390
	1.713	3.304	27.715	1.639	3.286	30.032	2.429
Average Trans time	1.787	3.772	50.245	1.830	3.476	50.415	1.874

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APPENDIX C. RISK MANAGEMENT

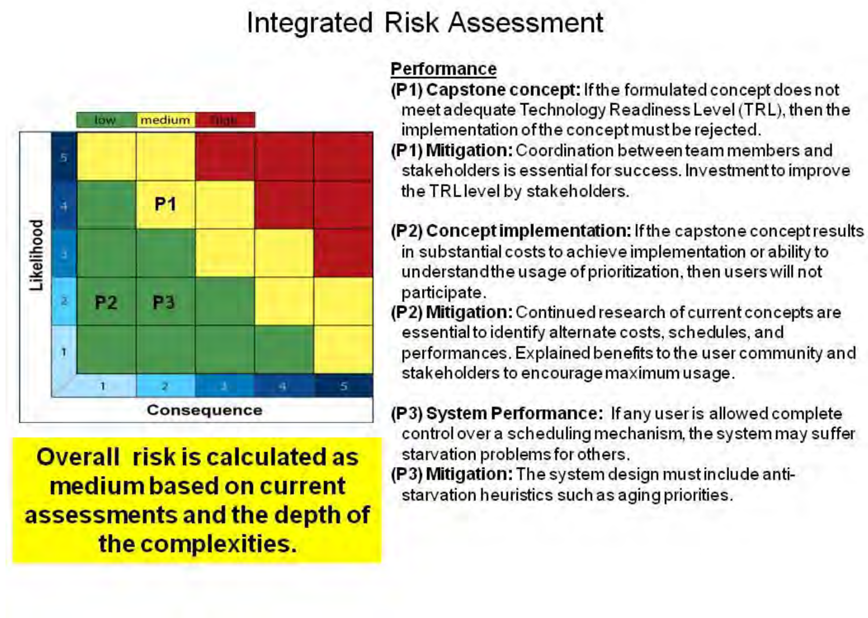

Figure 40. Integrated Risk Assessment – Performance

Figure shows the probability and impact of the performance measures of the three most likely risks [Risk Management Guide for DoD Acquisition, 2006].

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APPENDIX D: KEY TERMS

Ad-hoc - a set up with a particular purpose

Afloat – floating on top of water; on board a ship at sea

Ashore – not on a ship; on the land

Backlog – unfinished work that must be dealt with before any advancement can be made

Baseline – the standard to which all other things are to be compared with, a line used as a basis for comparison

Battle space – the location of fighting on a large-scale

Bottleneck – a narrow junction that slows progress and causes jams; one process is slower than another which hinders the overall process

Box-plot – a schematic representation that graphically illustrates the sample"s mean, the upper and lower quartiles (the box), and the outliers (whiskers).

Bits per second (bps) – the transmission of bits, either a binary one or zero, is sent/received within a second

Bus – a path for the transmission of computer data which is usually done from a peripheral device to the central processing unit

Byte (B) – the amount of computer memory to store a single character that is a group of eight bits

Capability – the ability of something/operator to accomplish a operation

Ceteris paribus – all things being equal; if everything being considered stays the same

Cipher – a code; a key is needed to decipher the code, that is letters are replaced with something else according to a system

Configuration – the way parts are arranged to fit together, the interconnection of software and hardware components in a computer system; spatial arrangement

Decomposition – break apart from complex to simple; broken down into its constituent parts; separate

Demodulator – extract a signal from a radio wave carrier that contains information

Depot – where military supplies are stored; a warehouse that stores things

Differentiate – finding differences between things; different due to its specialization or modification; mathematical derivative

Discrete – not connected, separate, distinct, unrelated; a variable with a finite value

Domain – the subject‟s scope; activity in an area for which someone is in control or ownership; a domain name, for example, ONLINE; a mathematical function‟s possible values

Enclave – a group that operates within a larger group

Enterprise – a new possibly risky venture; a mission especially one of some scope and complication

High level – elevated participation

Interface – where pieces of equipment meet; where physical boundaries interact and affect each other at the connection; where two computer devices exchange data flow

Infrastructure – the foundation for any system; the basic level within a complex organization

Integrate – several objects combine into a larger whole; incorporate; amalgamate

IPT – an integrated product team which consists of talented people from many different disciplines who become one in order to share the responsibility of work on a new product

Latency – the systems‟ measureable time delays; time measured in a network is usually concerned with how much time a data packet gets from one point to another

Lossy - a network link that is characterized by high packet drop rate and or data transmission errors due to unreliable and intermittent connectivity

Mega (M) – 10 ^ 6, 1,000,000, a million

Milli – 10 ^ -3, .001, one thousandth

Model – The representation of a system to be analyzed with assumptions on how the system works; a microcosm of mathematical and logical relationships within said model; a replica to gain understanding about how the system behaves.

Modulator – uses a baseband input signal that is transformed into a radio frequency or modulated signal

Needline – a line on an architectural drawing between two nodes that supplies necessary information for the flow of services

Net-centric, or netcentric – a continuously evolving and complex community of participants who have a shared vision of mission solutions that result in a capability that is greater than the sum of its parts

P-value – the statistical probability of obtaining a similar data set or worse when the null hypothesis, H_O, is true

Pairwise comparison – each entry is compared with the others in order to determine its ranking within a group

Prioritization – maximize success by arranging things in the order of importance

Protocol – a digital message format system that enables telecommunication between computer systems; network etiquette

Prototype – an original model built to test a concept and learn improvements in its class for later stages

Quality of service – managing the problems inherent to the Internet and other networks that cause jitter, delay, packet loss, and bandwidth availability problems in a cost effective manner

Quench – an induced delay through Internet control message protocol (ICMP) to decrease the traffic rate of data messages sent to an Internet host destination

Queue – a waiting line; a first in first out sequence

Re-engineer – trouble-shooting that requires redesign

Scenario – a collage of a series of actions; a proposed plan is outlined

Scope – the range of view where context values are associated with in an area

Simulation – is the use of a computer to evaluate a model (see model) by running data through the simulation in order to see the true characteristics of the model without actually building the model

Storyboard – a series of sketches; a primitive "blueprint" outlining a sequence of actions

Stove-pipe – one explicit application that very efficiently solves an issue

Subnet – abbreviated form of subnetwork, where a logical grouping of connected device nodes are in close proximity to each other; a separate part of the organizations network

Summits – one centralized event; the highest level one can achieve

Systems engineering – "Systems engineering is an interdisciplinary approach and means to enable the realization of successful systems," states the International Council of Systems Engineering (INCOSE).

Template – a pattern used as a guide to create something, a quick method to define projects‟ parameters or algorithms that are repeatable

Theater – war zone

Throttling – Used in network engineering as a traffic technique whereby the bandwidth is constricted by controlling package flow rates in order to minimize congestion

Trade-off – all outcomes could not be obtained at the same time so one thing was exchanged for another to achieve a balance between risk and return

Tukey method – John Tukey is the statistician who invented the box-and-whisker plot of the quartile values. The Tukey method simultaneously considers all possible pairwise differences of the means.

Validation – officially sanctioned; the act of being valid as defined in user documentation and requirements

"Vee" – the letter V

Verification – the act of proving accuracy with a test

Web browsing - using a web browser‟s software to display contents on the World Wide Web

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